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OF THE
American Institute
OF
Electrical Engineers

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Number 1

January, 1909

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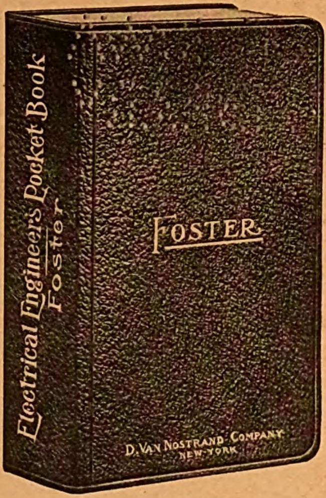

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Vol. XXVIII **January, 1909** No. 1

January Meeting A.I.E.E.

The two hundred and thirty-third meeting of the American Institute of Electrical Engineers will be held in the Auditorium of the Engineers' Building, 33 West Thirty-ninth street, New York, on Friday, January 8, 1909, at 8 o'clock p.m. Mr. Elihu Thomson, past-president of the Institute and electrician of the General Electric Company of West Lynn, Mass., will present a paper entitled, "Conditions Affecting Stability in Electric Lighting Circuits." The paper is printed in this issue of the PROCEEDINGS, pages 1–22, and paper contains an interesting account of the various methods tried during the last 30 years in the effort to obtains tability of current or potential, or both, in electric lighting circuits, circuits whose load is inherently unstable owing to the peculiarity of the arc-resistance falling with increase of current.

Professor Thomson takes advantage of this opportunity once more to remove the misconception that has been handed down for years, that the function of the air-blast mechanism on the Thomson-Houston arc-light machine was to blow out the sparks at the commutator. He says, on page 12, of his paper, that the real function of the air blast was to ensure the non-existence of heated gas at the zero current, and to replace it with cold air, thus preventing the next alternation from re-establishing the arc. We quote him in full on this subject:

> In apparatus in which potential differences of thousands of volts had to be maintained with only a single slot in the commutator between the brushes at such great potential differences, it can readily be understood that flashing or arcing over a slot might short-circuit or reduce the line current so much as to introduce a different kind of instability. Such a flashing or arcing in the slot was of the nature of an alternating arc. A segment of the commutator left the brush with a small trailing spark, showing a diminishing current, reaching zero at a small distance in advance of the brush. Immediately thereafter the potential of the segment was reversed and attained a high opposite value, which as in an alternating arc would jump the zero current position, especially if any heated gas remained in the slot. The writer has been frequently credited with having adopted as a bold expedient the well known air-blast mechanism to blow out the sparks at the commutator. Nothing could be further from the fact or more mistaken. The real function of the air blast was to ensure the non-existence of heated gas at the zero current to replace it with cold air and prevent the possibility of the next alternation re-establishing the arc and short-circuiting the commutator over the single slot between positive and negative brushes. The action to be secured was carefully reasoned out in advance of its trial and application. Without it the instability of circuit conditions would have rendered operation entirely impracticable owing to incessant alternating arcs between commutator segments. Although these considerations apply to apparatus which is rapidly being replaced by other means of distribution, the writer feels justified in here presenting them as matters of history not generally understood.

Minutes of December Meeting of the Institute

The two hundred and thirty-second regular meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers' Building, 33 West Thirty-ninth street, New York, Friday, December 11, 1908. President Ferguson called the meeting to order at 8:00 p.m.

The secretary announced that at the meeting of the Board of Directors held during the afternoon there were 88 Associates elected, as follows:

ASPESTRAND, TOLLE HAGBART, Electrical Engineer, Warren E. Mfg. Co., Sandusky, Ohio.

BALL, ALBERT, Asst. Professor of Physics and Engineering, Cooper Union; res., 865 Cauldwell Ave., New York City.

BELL, WILLIAM IRA, Superintendent, Marion P. Station, P.S. Ry. Co.; res., 68 Van Riepen Ave., Jersey City, N. J.

BLACKWELL, OTTO BERNARD, Engineer, American Tel. & Tel. Co., New York City; res., 19 Baldwin Terrace, Orange, N. J.

BOISEN, LARS NANNESTAD, Electrical Engineer, Grand Rapids Muskegon Power Co., Grand Rapids, Mich.

BOZELL, HAROLD VEATCH, Asst Professor, Dept. of Electrical Engineering, University of Oklahoma, Norman, Okla.

BUSH, ELI FRANKLIN, Salesman, Westinghouse Electric & Mfg. Co., Mechanicsburg, Pa.

CADWELL, WILLIAM RICHARD, Chief Electrician of General Office Blg., C. B. & Q. R.R. Co.; res., 867 W. Adams St., Chicago, Ill.

CARTER, CLIFTON CARROLL, Instructor, Dept. of Electricity & Mines, Coast Artillery School, Fort Monroe, Va.

CARTER, GEORGE REVILO, Student, Harvard, University, Cambridge, Mass.; res., 219 Park St., Watertown, N. Y.

CASTLE, SAMUEL NORTHRUP, Construction Engineer, Allis-Chalmers Co., 71 Broadway, New York City.

CENTERWALL, T. GEORGE J. D., Engineer Power House, The Gullspang-Munkfors Power Company,Gullspang, Sweden.

CHILTON, ST. JOHN, District Manager, Allis-Chalmers Co., 2225 Land Title Bldg.; res., 4308 Chestnut St., Phila., Pa.

CLARK, JAY ANDERSON, Foreman, General Electric Co.; res., 15 Glenwood Boulevard, Schenectady, N. Y.

CONLIN, JOSEPH, Salesman, Nagel Electric Co.; res., 2143 Putnam St., Toledo, Ohio.

COURSOL, AIME GEDEON, Superintendent, The Sorel Electric Co., Sorel, Quebec.

DE LAY, FREDERIC ABRAHAM, Instructor in Electrical Engg., University of Michigan; res., 551 Elizabeth St., Ann Arbor, Mich.

DENTON, FRANCIS MEDFORTH, Instructor in Electrical Engg. Practice, Carnegie Technical Schools; res., 308 Meyran Ave., Pittsburg, Pa.

DODDS, JAMES S., Member of Firm and Manager, Indiana Electric Company, Indiana, Pa.

ELKINS, BENJAMIN HARRISON, Superintendent and Electrical Engr., Mallison Power Company; res., South Windham, Me.

ELMES, CECIL F., Electrical Engineer, Sanderson & Porter, 52 William St., New York City; res., 359 Fifth St., Brooklyn, N. Y.

FOOTE, EDWARD T., Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

FROST, DONALD KARNE, Assistant to R. T. Dana, Consulting Engr.; res., 67 Riverside Drive, New York City.

GASKILL, WALTER WAGNER, Student, Harvard University; res., 14 Fairfax Hall, Cambridge, Mass.

GILMAN, WILLIAM FRANKLIN, Chief Electrician, Commissary Dept., Panama Railroad, Cristobal, Canal Zone.

GUELL, ANTONIO, Graduate Student, E. E., University of Illinois; res., 506 S. Mathews Ave., Urbana, Ill.

HAIL, JOSEPH CHARLES, Electrical Inspector, North Shore Elec. Co., Oak Park, Ill.; res., 174 S. Peoria St., Chicago, Ill.

HAMMER, MILBY ROY, Instructor in Mechanical Drawing, Univ. of Wis.; res., 701 W. Johnson St., Madison, Wis.

HARRIS, ROSS WINSLOW, Field Electrical Inspector, Wisconsin State Board of Assessment and R.R. Rate Commission, Madison, Wis.

HATCH, FRANK S., Manager, The Bountiful Light and Power Co., Woods Cross, Utah.

HATTERSLEY, HARRY ALFRED, Hattersley & Sons, Fort Wayne, Ind.

HERDEGEN, ROBERT TOWNSEND, Erecting Engineer, Allis-Chalmers Co.; res., 1303 Third St., New Orleans, La.

HIBNER, ALDIS EVERARD, Industrial Engineer, Rochester Ry. & Lt. Co., 34 Clinton St. N., Rochester, N. Y.

HILLEBRAND, WILLIAM ARTHUR, Instructor in Electrical Engineering, Stanford University, Cal.

HOLLISTER, VERNON LEO, Adjunct Professor of E. E., University of Nebraska, Lincoln, Nebraska.

INGLEBY, JOHN CONRAD BEDFORD, Ingleby & Co., Electrical Engrs., Elland Road, Leeds, England.

JACKSON, JAMES ALFRED, Electrical Engineer, General Electric Co.; res., 304 Clinton St., Schenectady, N. Y.

JAMES, LEONARD VAUGHAN, Assistant in E. E., University of Illinois Urbana; res., 505 E. Green St., Champaign, Ill.

JOHNSON, KENNETH SIMONDS, Student, Harvard University; res., 29 Weld Hall, Cambridge, Mass.

KINGSBURY, NATHAN CORNING, President, Michigan State Tel. Co., Telephone Bldg., Detroit, Mich.

KNOEBNER, HERMAN A., Chief Draftsman, Crocker-Wheeler Co., Ampere; res., 365 North 7th St., Newark, N. J.

LANDSBOROUGH, TOM RUTTER, Electrician, Tonopah Mining Co., Tonopah, Nevada.

LEBOVICI, JUSTIN, Electrical Engr., Ideal Electric & Mfg. Co., Mansfield, Ohio.

LEONARD, CHARLES, Manager, Baltimore Office, Franklin Electric Mfg. Co., 1112 Union Trust Bldg., Baltimore, Md.

LEONARD, JAMES AUGUSTUS, Chief Engineer, Bar Harbor & Union River Power Co., Ellsworth, Maine.

LOTT, ANTONE LYMAN, JR., Electrician, Omaha & Council Bluffs St. Ry. Co.; res., 1007 N. 22d St., So. Omaha, Neb.

MATHEWSON, ALFRED, Construction Engineer, R. E. Moore Co., Wilmington, Delaware.

MATUS, MIGUEL ANGEL, Telegraph Inspector, Interoceanic Ry. of Mexico; Jalapa, Vera Cruz, Mexico.

MCCABE, EUGENE FRANCIS, Vice-president and General Manager, Mifflin County Gas & Electric Co., Lewistown, Pa.

MCILHERAN, WILLIAM CARL, Salesman, Wesco Supply Co., St. Louis, Mo.; res., Birmingham, Ala.

MERVINE, GEORGE STICKLE, Engineer, Plant Dept., New York Tel. Co.; res., 153 E. 86th St., New York City.

NEIN, WILLIAM CONRAD, Student, University of Illinois, Urbana,; res., 305 E. Springfield Ave., Champaign, Ill.

NETH, DAVID B., Elec. Supt., The Connecticut Co.; res., 26 Crescent St., Waterbury, Conn.

NEWBY, JOSEPH HUGHES, Electrical Engineer, Noyes Bros., Melbourne, Australia.

NEWMAN, A. C., Electrical Inspector, Edison Elec. Illuminating Co. of Brooklyn; res., 403 Lexington Ave., New York City.

PARKER, ARTHUR, Asst. to Electrical Engr., Electrical Dept., New York Shipbuilding Co., Camden, N. J.

PARSONS, EDWARD DAVID, Operator, Hudson River Electrical Power Co.; res., 69 Maple Ave., Saratoga, N. Y.

POWELL, WILLIAM HENRY, Engineer, Electrical Dept., Allis-Chalmers Company, Milwaukee, Wis.

RATHBONE, RICHMOND LAURIN, Sales Engr., Westinghouse Electric & Mfg. Co., 1004 New England Bldg., Cleveland, Ohio.

Reid, Charles Roy, Instructor in Electrical Engineering, Univ. of Oregon; res., 914 Ferry St., Eugene, Oregon.

Reiff, George Ernst, Designing Engineer, Western Electric Co., Hawthorne; res., 868 Central Park Ave., Chicago, Ill.

Reilly, William F., Vice-president, James Reilly's Sons Co., 122–130 Centre St.; res., 12 W. 77th St., New York City.

Richter, Henry, Chief Electrician, Chicago Railways Co.; res., 943 W. Superior St., Chicago, Ill.

Ruel, Amai J., Electrical Expert, J. L. Gleason & Co., 200 Summer St.; res., 77 Pinckney St., Boston, Mass.

Rutherford, James Wilson, Power Agent, N. Y. & Queens Elec. Lt. & P. Co.; res., 1283 Summit Ave., Jersey City, N. J.

Saathoff, George Webster, Erecting Electrical Engineer, Westinghouse Electric & Mfg. Co., 610 Bank of Commerce Bldg., St. Louis, Mo.

Schnabel, James F., Sales Dept., Electric Controller & Mfg. Co., 50 Church St., New York City; res., 1464 74th St., Brooklyn, N. Y.

Shaughnessey, John Joseph, Sales Engineer General Storage Battery Co., Boonton N. J.

Sinclair, Stephen Lathern, Engineer, D'Olier, Engineering Co., 116 Liberty St.; res., 1043 Southern Boulevard, New York City.

Sked, Norman S., Engineering Assistant, N. Y. & N. Y. & N. J. Telephone Co.; res., Pennington, N. J

Sleeth, Montgomery, Engineering Apprentice, Westinghouse Electric & Mfg. Co.; res., 301 Welsh Ave., Wilmerding, Pa.

Smith, James Link, Superintendent, Leadville Light & Power Company, Leadville, Colo.

Snook, John James Archibald, Asst. Switchboard Engineer, Fort Wayne Electric Works; res., 502 W. Jefferson St., Fort Wayne, Ind.

Sprague, Roy Vernon, Foreman of Power House, Puget Sound Power Company, Electron, Washington.

Staunton, Gray, Directing Electrical Chemist, Gray Staunton Laboratory, 204 Lincoln Park Blvd., Chicago, Ill.

Stovall, Smith Lavender, Chief Engineer, Globe Light & Power Co., Visalia, Cal.

Strong, George Watson, Assistant Electrical Engineer, Cleveland Electric Illuminating Co.; res., 1223 E. 87th St., Cleveland, O.

Tisell, Gunnar Olaf Erik, Book Mfg. Man. McGraw Publishing Co., res.; 250 Manhattan Ave., New York City.

Tompkins, William Miller, Electrician in charge, John Wanamaker, Philadelphia, Pa.; res., 713 Pembroke Ave., East, Landsdowne, Pa.

Troy, Matthew Orpheus, Assistant to Sales Manager, Transformer Dept., General Electric Co., Schenectady, N. Y.

Upham, William Hall, Salesman, General Electric Co., 1518 Park Bldg., Pittsburg, Pa.

Van Meter, Rush Henry, Switchboard Operator, Prairie Pebble Phosphate Co., Mulberry, Fla.

Watley, William Franklin, 1st Class Electrical Mechanic, Norfolk Navy Yard, Portsmouth, Va.

Weniger, Willibald, Department of Physics, Oregon Agricultural College, Corvallis, Oregon.

Whitehurst, Obid Francis, Assistant Engineer, A. L. Drum & Co.; res., 2621 Lake Ave., Chicago, Ill.

Wiatt, Henry, Superintendent, Los Angeles Gas & Electric Co., Los Angeles, Cal.

Wintrode, Eduard Bion, Electrician, Pacific Lt. & P. Co.; res., 2927 Dalton Ave., Los Angeles, Cal.

Wolf, George, Western Electric Co., 463 West St.; res., 351 W. 15th St., New York City.

The secretary announced further that the following Associates were transferred to the grade of Member:

John Knowlton Robinson, Electrical Engineer and Agent, Westinghouse Electric & Mfg. Company, 116 Broad St., N. Y., and Iquique, Chili, South America.

Frederick D. Nims, Chief Operating Engineer, Mexican Light & Power Co. City of Mexico, Mexico.

Charles Roy McKay, Manager, Light & Power Department, Toledo, Railways & Light Company, Toledo, O.

Austin Burt, General Superintendent and Engineer, Citizens Gas & Electric Company, Waterloo, Iowa.

Edgar Buckingham Holden, Jr., Electrical Engineer, with Viele, Blackwell & Buck, 49 Wall St., New York City.

John Boswell Whitehead, Associate Professor, Applied Electricity, Johns Hopkins University, Consulting Electrical Engineer, Baltimore, Md.

Henry Edward Mordaunt Kensit, Electrical Engineer, 19 North St., Toronto, Canada.

George Carl Shaad, Associate Professor of Electrical Engineering, Massachusetts Institute of Technology, Boston, Mass.

James Edgar Miller, Electrical Engineer, Westinghouse Electric & Manufacturing Company, Pittsburg, Pa.

Standen Leonard Pearce, City Electrical Engineer, Electricity Works, Manchester, England.

W. S. Murray, electrical engineer of the New York, New Haven & Hartford Railroad Company then presented a paper entitled, "The Log of the New Haven Electrification." About 1000 members and guests attended the meeting, which was prolonged until after midnight. The paper was discussed by Messrs. Calvert Townley, W. J. Wilgus, B. F. Lamme, A. H. Armstrong, N. W. Storer, H. P. Davis, E. B. Katte, L. B. Stillwell, C. L. Muralt, Philip Torchio, A. H. Babcock, M. M. Davis, C. P. Steinmetz, Wm. McClellan, Philip Dawson, and W. S. Murray.

[The discussion will be printed in the February PROCEEDINGS.]

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before February 1, 1909.

8100 de la Rochette, G. de P., N. Y. C.
8101 Jones, Jos. S. Norfolk, Va.
8102 Webster, Louis D., Chicago, Ill.
8103 Voss, Maxwell, Baluarte,Coah,Mex
8104 Leite,L.de C.,Rio de Janeiro, Brazil
8105 Jakobsen, B. F., Roosevelt, Ariz.
8106 Jansen, Edgar W., Chicago, Ill.
8107 Malan, Henry E.M.,Hamilton,Can.
8108 Whitmore, J. D., Grand Isl., Neb.
8109 Atkinson, R. W., Wilkinsburg, Pa.
8110 Seager, Chas.A., Christchurch, N.Z.
8111 Schoel, Wm. A., Corvallis, Oregon.
8112 Fulton, Robt. N., Dunedin, N. Z.
8113 Clark, Chas. C., Vancouver, Can.
8114 Parrott, R. G., Manchester, Eng.
8115 Carbo, L. A., Guayaquil, Ecuador.
8116 Bolton, F. C., Agr. College, Miss.
8117 Johnson, C. A., Lawrence, Kan.
8118 Grover,Marcus A.,Birmingham,Ala
8119 Vogel, J. C., Jersey City, N. J.
8120 Pastoriza, Hugh, Provo, Utah.
8121 Barthell,E.B.,Salt Lake City,Utah.
8122 Frank, Eugene, New York City.
8123 Hughes, Chas. W., Joliet, Ill.
8124 Bowers, H. C., Los Angeles, Cal.
8125 Stearns, Wm. G., Los Angeles, Cal.
8126 Bischoff,Eugen M.,River Forest,Ill.
8127 Young, Chas. E., Marysville, Cal.
8128 Ralston, L. C., San Francisco, Cal.
8129 Jones, Geo. H., Philadelphia, Pa.
8130 MacIlraith, Evan J., Ithaca, N. Y.
8131 Krouse, Chas. S., Aspinwall, Pa.
8132 Ricksher, Theo., Iowa City, Ia.
8133 Harnden, J. D., Schenectady, N. Y.
8134 Boardman, Chas., Baltimore, Md.
8135 Robinson, C. Schenectady, N. Y.
8136 Smith, Oliver, T., New York City.
8137 Stone, Stuart R., Brooklyn, N. Y.
8138 Cox, Thos. J., Tollestone, Ind.
8139 Chapin, A. L., Chicago, Ill.
8140 Watson, Jay R., Stamford, Conn.
8141 Groce, George H., Chicago, Ill.

8142 MacLean, Daniel W., Orono, Me.
8143 Baker, Jas. N., Stamford, Conn.
8144 Mosiman, Levi, Morton Park, Ill.
8145 Clinch, Edw. S.,White Plains, N.Y.
8146 Jacobus, R. E., Ridgefield, N. J.
8147 Ellicott,W.J.,LaCananea,Son.,Mex
8148 Bart, John G., Cakeburg, Pa.
8149 Ames, Azel, Yonkers, N. Y.
8150 Hegarty, Geo. D., Waterville, Me.
8151 Barker, Chas. A., Atlanta, Georgia.
8152 Paca, Wm. S., Oil City, Pa.
8153 Morris, John M., Los Angeles, Cal.
8154 Hodgson, F. M., Plymouth, Ind.
8155 Scott, H. H., Montreal, Canada.
8156 McIntyre, A. B.,Schenectady, N.Y.
8157 Bailey, C. E., New York
8158 Ichiro, Ito, Tokyo, Japan.
8159 McMullen, T. E. Jr., Seattle,Wash.
8160 Hall,A. J., Winchcombe,Glos.,Eng.
8161 Foster, Edmund, Norfolk, Va.
8162 Beyer, J. W., Schenectady, N. Y.
8163 Duncan, W. G., Norfolk, Va.
8164 Eakins,A.A.,Governor's Island,N.Y
8165 Hall, Earnest, Chicago, Ill.
8166 Bishop, W. D., Schenectady, N. Y.
8167 Barrett, W. E., New York City.
8168 Heath, Stephen T., Brooklyn, N.Y
8169 Brydon, H. B., Pueblo, Colo.
8170 Woodward, C. D., Gt. Falls, Mont.
8171 Duncan, O. J., Jr., Ft. Worth, Tex.
8172 Nelson, E. E., Ft. Worth, Tex.
8173 Doremus, W. S., New York City.
8174 Sunderlin, E. A., Colorado Springs.
8175 Jacobs, R. C., East Orange, N. J.
8176 Fitting, R. U., New York City.
8177 May, Oscar S., Lockport, Ill.
8178 Colburn, A. R., Helena, Mont.
8179 Canizal, J., San Juan, P. R.
8180 Taylor, V. E., Stamford, Conn.
8181 Shaw, H. R., Schenectady, N. Y.
Total, 82.

Applications for Transfer

Recommended for transfer by the Board of Examiners, December 11, 1908 Any objection to these transfers should be filed at once with the secretary.

Harry Archer Hornor, Electrical Engineer, New York Shipbuilding Co., Camden, N. J.

Allan B. Field, Electrical Engineer, Allis-Chalmers Co., Milwaukee, Wisconsin.

Edwin Fitch Northrup, Manufacturer of Scientific Electrical Instruments; Secretary, The Leeds and Northrup Co., Philadelphia, Pa.

Some Impressions of the United States Patent Office*

For a temporary employment extending from a few months to several years, the United States Patent Office offers opportunities which are ideal. Since the profession of engineering is fundamentally the profession of invention, and the engineer's ideas are his capital, or stock in trade, a knowledge of the means of protecting these ideas is of considerable importance. And this knowledge a term in the United States Patent Office gives.

My experience at the patent office began one June morning with the taking of the oath of office. This process consisted in presenting my credentials, filling out several blanks certifying that I was verily and truly the same person who had taken the examination, and winding up with a solemn declaration that I would defend and uphold the Constitution of the United States, and would faithfully serve the government.

This formality completed, the process of introduction was begun and I was made acquainted with the commissioner of patents, assistant commissioner, etc., including the major dignitaries of the office. Throughout the officials were extremely kind and sociable, this being a distinctive characteristic of the office, which gives the impression of an enormous school, rather than one of the most overworked of the governmental departments. This fact, together with the interesting nature of the work and the fact that almost without exception, the examiners are college or university men, makes the position of patent examiner one of the most desirable under the government.

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* A paper on "Summer Experiences" read by William A. Darrah at a meeting of the Worcester Polytechnic Institute Branch, October 9, 1908.

Among those to whom I was introduced was an amiable old gentleman with white hair and beard, and the manners of a country deacon. He proved to be the primary examiner of the division to which I had been assigned, and had the reputation of being one of the oldest and kindliest men in the whole office, a reputation which he abundantly lived up to. Incidentally, I found out later that he is one of the best lawyers in Washington. In company with him I went around to the division where I was to work, and again underwent the process of introduction, this time to the examiners with whom I was to be more intimately associated. In my division there was, besides the primary examiner, four assistant examiners, a clerk, and a most attractive stenographer. A very interesting group they were, typical of the personnel of the office. Two of the examiners had been union soldiers in the civil war, while the third was a graduate of the United States Naval Academy.

The division occupied three large, high studded rooms, the ceilings highly and uselessly decorated, after the manner of government buildings, while the walls were lined with file cases containing the records of the division, the tops of the cases being piled high with law books, decisions of the courts and the commissioners, and a sprinkling of technical volumes.

Each room was provided with several large desks littered with papers and books, and to one of these I was assigned, being given a copy of the annotated patent laws of the United States. Here my legal education began.

At this point some idea of the division of work and the duties of the examiners may be pertinent. The office is divided into 41 divisions each supposed to contain all allied subjects of a certain art or branch of industry. Thus machine tools, simple tools, metal working devices are classed in one division; surgery and undertaking are suggestively classed together; and with the same cynical wisdom bread, cakes, and pies are grouped in the same division (under "plastics") with Portland cement, plaster of paris, etc.

In addition to the 41 divisions of legal and technical work, there are also the divisions of publication and classification. In the latter all applications for patents are casually examined, and assigned to the division dealing with the particular subject to which it relates. Within the division each examiner has a special branch or branches of work, called his "art" in which he is supposed to be especially skilled. When an application has been assigned to a particular division, the primary examiner in the latter, reassigned it to the assistant examiner in whose art it belongs. The application is then called a "case" after the legal phraseology.

It now becomes the duty of the examiner to whom it is assigned to make a careful examination of the case, to see that the legal forms are complied with, that the drawings and specifications agree, and are as clear, concise, and unequivocal as possible. After the examination as to form has been made, the "search" is begun. This consists in examining all previous patents in the class or sub-class of the art to which the application appertains, or closely related arts, to determine whether previous patents have been granted on the device in question. Contrary to what might be expected, the claims and specifications of previous patents are not examined in making the search, (except in cases of doubt), but the drawings are inspected, and if the claims of the applicant can be read upon these drawings, those claims are noted and rejected. Originally other sources were used in the search for anticipating references, these sources being encyclopedias, magazines, text-books, and devices already constructed. However, with the growth of the office, these were gradually abandoned, and dependence placed solely upon the office records.

Having made the examination and search, the next step is to make what is called the "action," which consists in writing a memorandum in the form of a letter, stating all formal objections to the application and the reasons for its rejection. Here the examiner has considerable personable latitude, which is frequently used as a means of disciplining unscrupulous or careless attorneys. This memorandum is handed or read to the stenographer, who makes two typewritten copies of it, one for office reference, while the other is sent to the applicant or his attorney.

If the application is not rejected and is in good form throughout, it is sent to the issue division, and after more or less " red-tape " the patent is granted to the applicant.

Naturally, and fortunately for the office, 90 per cent of the applicants are represented by attorneys, who transact the entire legal business of the inventor very much more expeditiously and probably more satisfactorily than he could himself. It is an old saying, and one well proved by experience, that " the man who handles his own case has a fool for a client."

As the examiner is thrown much into contact with the attorneys personally, or with their cases, he very soon learns their characters and methods. And there are all classes of attorneys, from the most conscientious expert, to the charlatan who takes the cases dropped by others. The work of the careless attorney is given a rigid examination, and no mercy shown in objecting to claims or forms, while the cases of more conscientious lawyers are less severely dealt with. This is not, as it might appear, a form of favoritism, but merely a means of causing the attorneys to prepare their own cases, instead of throwing that work upon the office, which is already overworked.

As the examiner handles applications from all kinds of people in all parts of the world (for there are a large percentage of foreign applicants), he naturally comes across many curious errors and ideas. Thus a certain legal light from California, more versed in legal than technical details, recently presented several cases describing a " Paul and Rachel " wheel evidently considering " pawl and ratchet " a biblical quotation. Then there is the class of attorneys, who having a marked antipathy to friction, call all pivots " antifriction pivots," while another group of practitioners call all devices automatic. The applicants from abroad, notably German inventors who try to conduct their cases after the rules of their home office, are another group who make interesting errors. All applications must be in English, and the quaint German-English of these specifications is usually harder to read than German itself.

The patent office is also the hunting grounds for all varieties of cranks and freaks. The old attempts to patent perpetual motion devices are so well known as to require little comment. They are still being presented, however, variously disguised, for the patent office will not accept such applications knowingly. One presented this past summer, which came to my notice, was a machine which operated by the expansive force of freezing water, which was alternately passed into two cylinders, frozen, and then forced out, thus doing work. In such cases, it is the custom of the examiner to request a working model. This requirement generally silences the freak inventor.

Among the curious applications presented may be mentioned the dry process of purifying water which consisted in " first reducing water to the solid state, crushing it to a fine powder, passing it through a fine-mesh seive, and then by the application of a gentle heat reduced once more to the liquid state." The applicant was evidently used to sizeable impurities.

Compared to some departments of the government, the patent office is remarkably free from evidences of "graft." It is worthy of note that almost any dishonest or mistaken issue of a patent can be corrected by application of the injured party to the courts, for while the commissioner of patents may not annul a patent, he may grant one of an earlier date. Not to be classed under the head of graft, is the kindness of one of the largest firms of patent lawyers in furnishing the *Scientific American*, free of charge to all examiners in the patent office. Formerly boxes of cigars, complimentary railroad tickets, etc., were mysteriously circulated among the officers, from unknown (?) sources, but this practice has decreased somewhat.

The position of the examiner may need a little explanation. He is a kind of lower court, in fact, he, with the primary examiner, form what is called the lower tribunal of the office. He examines the cases presented and requires amendments and corrections, which if not complied with work rejection of the application. Appeal may be taken from this decision to the examiners in chief, and from them to the commissioner, after which the case goes to the United States courts. Thus the examiner is the lowest tribunal in the series. The examiner gives hearings and interviews, and considers motions and amendments very much as a judge of a lower court would do.

Considering the advantages of the position of examiner, they are many. It is a governmental position, hence certain for a lifetime if desired. The work is not difficult, and is very interesting. There is considerable opportunity for outside work as the hours are 9 a.m. to 4:30 p.m. The atmosphere of the office is most congenial, the examiners are all well educated men, and there is an air of kindliness and good-fellowship found in almost no other occupation. The office also gives one an impression of peacefulness, and contentment as no one ever hurries through the old corridors, and each works when and as much as he wishes in a manner most restful and novel.

The principal objections to a permanent position in the patent office are mainly due to its permanence or certainty. The salary of the office is not large, and advancement slow, but both are certain to any man of very moderate ability. The relation of the salary in the office to the average technical graduate indicate that while the engineer starts at a lower salary, yet he eventually crosses the salary of the examiner and later considerably exceeds it.

In the matter of salary, merit and ability have little effect in government service, which rather discourages hard work. The great chance of the able man however is his chance to study patent law and eventually after being admitted to the bar, to start in a business for himself. The income of a patent attorney is limited only by his ability. While there are a number who make a bare living, there are a large number whose incomes range from $2000 to $20,000 per year.

Some Experiences with the Boston Elevated Railway Company*

I went to work for the Boston El. Ry. Co. in the capacity of pitman on the elevated division at Sullivan Square. Now the duties of a pitman are not very inspiring. I thought I was going to start off at least by being with some one who worked on electrical jobs, but these were my first duties. I had a big monkey wrench, a lantern, machinist's hammer, box containing various sizes of cotter keys, nuts, screws, etc., a gauge for measuring the distance apart of wheels. I pounded all wheels to test their soundness, gauged them to see that they had not spread beyond a prescribed limit. I was supposed to have an eye out for missing bolts, nuts, cotter keys and the electrical connections from the third rail shoe to the car body. This latter consisted in shoe, shoe-beam, braid, fuse, and lead. The work was hard as the beams are very heavy and were being constantly changed. The work was not only hard but very dirty. I was generally one even color all over about one-half hour after starting in to work at night, a greasy black.

My opinion of the work that I was on

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* A paper on "Summer Experiences" read by R. T. Pollock at a meeting of the Worcester Polytechnic Institute Branch, October 9, 1908.

at first was not very good, but when I was changed, and ever since, I have been very glad that I went through it. I learned the importance of trucks, gears, brake-rods and shoes, and in fact everything of a mechanical nature about a car and a very good type of car at that. Of course the railroad commissioners are more strict in regard to elevated service than surface lines, and I must say that the company did all in its power to insure safety to the public. All workmen had to report on every car inspected or repaired every morning. This gave the company something to fall back on in placing the blame for any trouble.

A vacancy occurred in the inspection department and I was ordered to fill it. This change was very desirable. I was made inspector of motors after having been well instructed in the duties. The work on motors was very interesting. It consisted in a thorough examination of brushes, brush-holders, leads, commutator, and all visible parts of the motor. All small parts such as brushes, springs, etc., I was supposed to renew, but on finding an open circuit, short-circuit, ground, flat commutator bars, open segment, the car was sent over to the shop that I had just come from, stripped of all small parts, the trucks taken from under the car and lowered to the repair shop below by means of an hydraulic elevator.

It is well to mention here that the system of control on the elevated cars at that time was a well-known multiple unit system. The reason for referring to the system of control is that considerable trouble was being met with in regard to motor flashes, grounds, short-circuits, etc. Later, when the control system was changed, the greater part of the trouble was eliminated. I do not state this with any intention of criticizing any system, but simply to show a practical illustration of the well-known fact that the cylinder type of control had its limits and had reached them on this road. The flashes were severe and destructive. Sometimes one or more of the large brush-holders would be melted into uselessness, again a heavy motor lead would be burned completely off. In a few cases a large hole would be found burnt in the middle of the armature, through coils, laminations, and spider.

A car was on the doubtful list one night and we had a motorman run it out around the loop. We had not gone far when the motor flashed, and as we had the floor pieces up the flash came up into the car. It completely filled the motor opening in the floor, an opening about 2 ft. by 3 ft., and jumped up into the air about 4 or 5 ft. Of course it was all over in a second, but was very severe while it lasted. An inspection of the motor disclosed one end of a brush-holder melted off. Considering the conditions we can best imagine the conditions existing on the road when two or more brush-holders were put out of commission.

A peculiar thing that I had to look out for and which caused considerable trouble was what I will call the decaying of the conductor in a motor lead where it entered the motor. A rough examination of the lead showed nothing, as the insulation would generally remain in fair condition, yet there would be no electrical connection. The continual twisting and turning of the leads when the car made curves was the cause of this trouble. Another thing that was ever present to cause electrical trouble was carbon steel dust which coated and stuck to everything under a car.

It was while working on motors that the entire shop crew was called out one night as a wrecking crew to help get a car on the rails. In some way a switch was thrown before the train was entirely past it, the result being that the last car tried to go in two directions at the same time. The weight of the three leading cars was sufficient to keep the forward truck on the main line, but the rear truck went off on a siding. The method used to get the truck and car on to the main line again, was this: First the car body was lifted clear of the truck by means of jacks. The king bolt was drawn and then the truck was raised by jacks, worked over on to the main line and afterwards the car body. When both were in proper position again, the king bolt was put back and the main line was cleared. In working on this car it was necessary that the third rail remain alive so that we could have light to work by. For protection we lashed boards around the live rail and made it a point not to touch any rail of any kind.

While working on motors a test was made upon the motor brushes. This test showed me the importance of tension and fitting brushes to the commutator. It made me somewhat familiar with the different kinds and manufacture of carbon brushes and their action under test. Some would not stand a trip through the subway and would come in all broken up, in some cases the brush entirely disappearing and opening the circuit.

A vacancy occurred in the general work of inspection for a short time and I was called on to help out. This meant jumping at any trouble of an electrical nature that a car was sent in for, and trying to get the car back into service as quickly as possible. In some cases a car would come in reported " dead." Being acquainted with just what would cause this, I went to work. In some cases a controller cylinder would be found a melted mass of iron and copper, again the cylinder would be all right but all the main contacts or fingers would be found burnt entirely off. Sometimes it would be the reverse cylinder or burnt out relay coils. In a lot of cases it took a long time to locate the trouble. A common thing that occurred was known as the " jumping of a car," due to one or more fingers being burnt off. This would cause the car to run slowly when the others were picking up and then make a lurch ahead when it finally made the next step on the cylinder, due to unequal cutting out of resistance.

When I came to work for the electrical engineer of the road my experiences were of a different nature and conditions all round were different. The work was more of a technical nature, yet it brought in great opportunity for practical observation in almost every class of electrical work. I gathered in all of the information I could whether I was personally on the piece of work or not, and I found everybody willing to give any information that I desired.

My first work was on the conduit system. I had nothing to do on this work outside of the office however, but gained a good general idea and some useful data in regard to such work. I was next shifted around in the different departments, doing a good deal of drawing for construction and feeder work.

The first chance to get out on the structure came when a couple of us were ordered to test a tachometer on a five-car train and find its error. We simply marked off a certain distance with pieces of board nailed to the structure and then with our tachometer installed on the head car of the train timed the train over the distance. I guess that we made about fifteen trips around the circuit before we obtained data that seemed accurate enough to turn in to the engineer.

Another test run was on the motors that run the escalators at State Street station of the new Washington Street tunnel. This was a heat run and for a load a new idea was adopted. All the Italians that were working in the tunnel were made to climb on the escalators and keep on them all the time, either going up or coming down. This test was run from early morning to late at night. The rise in temperature was calculated by the resistance method.

A number of line voltage tests were run during the time that I was there. These tests consisted in reading the voltage between trolley and rail at some remote point of the system and at intermediate points back to the power station. By the results of such tests it was easy to decide whether there was copper feeder enough out on the poles of a certain section.

When I got into the feeder department I remained there until leaving the company for school. Here I did a lot of drawing, such as feeder maps, construction drawings, etc. I also did a lot of running around all over the system. Here I became acquainted with the methods of figuring for a feeder installation, methods of distribution, sectionalizing, ground-returns, switches, etc. It was in this position that I was enabled to gather information in regard to the system in general.

There are ten power stations in this system, two of which are gas engine plants. In addition to this there are two synchronous-converter sub-stations. There are a good many types of engines used in these power stations, both old and new.

As I had an opportunity to investigate the new Washington Street tunnel, having had some work there, it might interest those here if I gave some of the most striking things to be noticed about such a piece of work.

The construction of this tunnel was attended with the greatest of difficulties. It passes under the foundations of the tallest buildings in the city. One building is worth especial mention, the Ames building. This building has a height of over 200 feet above the earth on which its foundations rest. The tunnel was built so that it was necessary to pass under a portion of this foundation. The tunnel also passes under the East Boston tunnel near State Street. There is considerable improvement over the old subway. For instance in the matter of grades the new tunnel is about ideal. Coming into stations the grade is up to assist in braking, while going out of stations it is down grade, to assist in quick starting. All stations are designed for eight-car trains, although when it is opened six-car trains will be run at first. In the matter of lighting, should their own system break down, the Edison system would be instantly and automatically thrown in on the tunnel lights.

Sections and Branches

UNIVERSITY OF ARKANSAS BRANCH

A meeting of this Branch was held on December 3, 1908, in the engineering hall of the university. Mr. T. D. Williamson read an abstract of a paper on "The Manufacture of Okonite." The various steps in the process of manufacture was illustrated by means of lantern slides. Mr. Paul Mardis read the Institute paper entitled "New Types of Incandescent Lamps."

ARMOUR INSTITUTE OF TECHNOLOGY BRANCH

The Commonwealth Edison Company's method of operating their sub-stations was the subject discussed in Mr. Petty's paper given November 19, 1908, at the Armour Institute of Technology Branch.

Having been in the employ of this company, Mr. Petty was well able to point out the many good and ingenious devices used by them. The diagrams which the speaker had drawn previous to the opening of the meeting made it possible easily to follow his explanations. Methods of handling emergencies and elimination of abnormal conditions were emphasized. The practice followed by the company when shutting down or starting up of converters, transformers, etc., was made known, and was the cause of much discussion following immediately after the conclusion of the reading of the paper. Incidentally the speaker mentioned some of the following points: the use of the current leads in place of a standard shunt for low-tension ammeters, the corresponding potential leads so selected and arranged as to neutralize the change of resistance in the equivalent shunt; star-connected generators with grounded neutral automatic auto-transformers; overload capacities of apparatus; floating battery system; etc. In conclusion the speaker pointed out occasional exceptions in regard to the company's usual method of operation.

On December 3 another meeting was held, at which 36 members and visitors were in attendance. The subject for the evening was "The Alternating-Current Single-Phase Commutator Motor," presented by Mr. Tracy W. Simpson.

A blue print syllabus covering the scope of the talk was distributed to those present. This covered a collection of circuit diagrams of the energy and exciting circuits of various forms of motors, as developed both in this country and in Europe, together with a brief explanation of the principle of the design of each type. Considerable interest was taken in the syllabus.

Each type of motor was studied from the standpoints of: 1. Commutation of load component of current. 2. Commutation of short-circuit component of current. 3. Rotor reaction. 4. Power-factor. 5. Torque per volt-ampere. 6. Ability to operate on direct current.

The various methods of improving operation along these lines, as exemplified in the various types of motors, were considered in some detail. In addition to explaining many of the complex phenomena of operation, the new method of improving power-factor, consisting of an auxiliary winding on the exciting field connected as a shunt across the mains, was illustrated by means of vector diagram. This method is due to Osnos,of the Felton Guilleaume Lahmeyer Werke.

Attention was called to the superior operating characteristics of the series repulsion motor, as well as to the general improvement attainable by motors having both stator and rotor power. It was stated that this motor compared unfavorably with the compensated series type, employing resistance leads, for long continued over-loading at starting; such as would be occasioned by the wheels of a locomotive being locked from too heavy trailing load.

The presentation of the paper was followed by a general discussion by visitors and members of the Branch in which much additional interesting information was brought out.

Atlanta Section

The annual meeting of the Atlanta Section was held at the Heptagon Club, Grand Building, December 8, 1908, at 8 p.m., with Mr. M. E. Bonyun presiding. Ten Institute members and one visitor were present. After the reading of the minutes of the preceding meeting, officers for the ensuing year were elected as follows: W. R. Collier, chairman, E. P. Peck, secretary, J. N. Eley, vice-chairman; George J. Yundt and E. H. Ginn, managers. The election of officers was followed by the reading of correspondence transmitted from the Institute headquarters and from the secretaries of several of the Branches. Mr. A. M. Schoen introduced the subject of "Circuit Breakers", which was discussed by the members present. The Institute pamphlets were distributed and topics were selected for the next meeting, which is to be held January 5, 1909.

Boston Section

The regular monthly meeting was held on Wednesday, November 18, 1908, in the auditorium of the Edison Building. Dr. A. E. Kennelly presided. About 175 members and guests were present. Mr. L. L. Elden abstracted the Institute paper "High Potential Underground Transmission", by P. Junkersfeld and E. O. Schweitzer. Notes and comments relative to the system of the Boston company were added, and illustrated by lantern slides. Among the points brought out were the following:

Underground cable systems of 11,000 volts and under, if properly made, installed and operated, will give at least equally and probably more reliable service than most of the other parts of the electric power stations of which the cable system is a part.

When local and commercial conditions justify, pressure as high as 25,000 volts can be used satisfactorily, even for systems aggregating 100 miles of cable. No single line of such a system should be longer than about 20 miles. If higher voltages are needed to meet operating requirements and can be justified commercially, special construction will be necessary to overcome limitations in paper, rubber or varnished insulation.

On comparatively short lengths underground or under water, as a part of a long overhead transmission line, cables operating at 40,000 volts can be used.

Potential rises of 50 per cent and 100 per cent are not uncommon in large cable systems, although this fact may not always be manifest, owing to a high factor of safety.

Definite knowledge of what actually occurs in large high-potential underground systems is still meagre, especially relative to intensity and frequency of surges, heating effects and critical temperatures for various kinds and thicknesses of insulation, corona effects and similar matters.

In the Boston system failures in transmission lines are the smallest item of disturbance. In the overhead systems the troubles are ten to one in comparison with the underground cable system, almost all of these occurring in cable newly installed. The troubles lie largely in the power transmitted, for example, at 6600 volts, 2500 kw. is considered the maximum capacity of the standard cable used, and the interruption of that capacity disturbs the system appreciably in some locations.

That such stations as those of the Commonwealth and Boston systems would probably be out of the question with reciprocating engine units, but with the steam turbine station the convenience of installation and operation is apparently as great with 50,000 kw. as with 15,000 kw. with the reciprocating engine.

That theory guiding cable construction is far behind the art of generator construction.

That the oscillograph is of value to the transmission system in the same order as the wattmeter and other instruments. That in matters of studying lightning protection it is coming to have an important place.

That breakdown in cables usually occur after a ground, or more often after a short circuit on a part of the system, perhaps external to the cable system, particularly if connected to an overhead system.

That high potential tests on the cables are likely to destroy something needlessly.

That a very good test of the strength of the cable to withstand disturbances could be obtained by an equivalent spark-gap measurement.

That the oscillograph, on account of the shortness of duration of its record, has shown a weakness in its ability to catch the high points of sudden potential rises; this being illustrated in the fact that none of the records shown in the paper accounts for the voltages indicated by the discharges of the spark gaps.

CLEVELAND SECTION

The meeting of October 19 was held in the Electrical Building, Case School of Applied Science. It was preceded by the usual informal dinner. The subject, "Protective Relays", was opened by a paper by Mr. F. F. Rossman. Mr. Rossman dealt with the subject in a general way, laying special stress on the inverse time element in the protection of high tension cables. This brought forth considerable argument and discussion, several members producing samples of various types of relays, with curves of setting. The meeting proved of special interest to central station men.

At the Nov. 16 meeting Mr. P. S. Bailey, of the arc lamp department of the General Electric Company, gave a very interesting paper on "Twenty-five Cycle Arc Lighting". This took up the subject from the standpoint of the suburban railway operator, giving various methods and comparative figures on the lighting of small villages by excess power of the traversing electric roads. Among the points brought out in the discussion were the effects of 25-cycle Nernst lighting, and some of the general effects and results of 25-cycle illumination, as well as the electrical difficulties.

UNIVERSITY OF COLORADO BRANCH

The regular meeting was held Thursday, November 19, 1908, at 7:30 p.m. The following program was carried out: A paper by Mr. Berg taking up the history and manufacture of incandescent lamps. Mr. Jenkins gave his third talk on practical wiring, taking up supports for wires. This was followed by a talk on transformers by H. L. Ireland. Mr. Ireland briefly outlined the theory of transformers, and then gave a description of the method of drying them by means of internal heat. Thirty members attended the meeting.

ITHACA SECTION

The second regular meeting was held on Thursday, November 19, 1908, with 130 members and visitors present. Professor H. H. Norris gave an experimental demonstration of " Atmospheric Insulator Losses in Transmission Lines." Various corona effects were shown, and by means of wattmeter measurements the corresponding power-losses were determined. The 60,000-volt transformer used in these experiments was the one designed and constructed by Professor H. J. Ryan and used in his famous experiments. This demonstration was appropriate in view of the recent discussion before the Section, of Mr. Mershon's Atlantic City convention paper. Where such experiments are practicable at Section meetings they go far to arouse interest in the Institute papers.

The third regular meeting of the Section was held on Friday evening, December 11, 1908. Professor H. Wade Hibbard, head of the railway mechanical department of Sibley College presented a paper on " The Handling of Men ". This topic is one of unusual interest, but it is also one that receives comparatively little attention in technical schools.

Professor Hibbard outlined the various features of executive work, and pointed out the essential elements of successful coöperation between employers and employes. He advocated courses of instruction in handling of men for undergraduates in technical schools, and instanced the Charlottenburg Technical High School of Berlin as an example. Professor Hibbard has had large experience, and has many opportunities for observation. The results of all these were condensed into a trenchant and stimulating paper. The presentation of the paper was followed by a lively discussion, in which particular attention was given to the problem of the treatment of foreign labor in the American shop and factory. In closing the discussion Professor Hibbard paid a high tribute to Italian and other European workmen, and stated that when they were properly understood they could become very efficient mechanics. In view of the fact that the local branch of the American Society of Mechanical Engineers was formed on December 10, the following resolution was passed by the Ithaca Section of the Institute.

" Resolved that the Ithaca Section of the American Institute of Electrical Engineers extend to the officers and members of the Cornell University Branch of the American Society of Mechanical Engineers, recently formed, best wishes and assurances of hearty coöperation in their work and plans."

UNIVERSITY OF KANSAS BRANCH

The University of Kansas Branch held its regular monthly meeting on November 21, 1908 in the Blake hall lecture room. The total attendance numbered 30. Professor C. A. Johnson gave a description of the apprenticeship system of the Westinghouse Electric & Manufacturing Company.

The December meeting took place on the 3rd instant. Mr. W. H. Reynolds spoke on "The Growth of Electric Plants in the City of New York During the Last Eight Years." Twenty-five members and guests were present at the meeting.

Lewis Institute Branch

One of the most successful meetings ever held by Lewis Institute Branch was that on the evening of December 2, 1908 at which an audience of over 400 assembled to hear an address on "Rehabilitation of Chicago Street Railways," by Ralph H. Rice, assistant engineer, Board of Supervising Engineers, Chicago Traction.

Mr. Rice called attention to the prevailing tendency for the public control of all public utilities, which was well illustrated in the new franchises of the Chicago traction companies, in which the Board of Supervising Engineers, thereby created, corresponds to a public-service commission. In tracing the history of the traction problem in Chicago for nearly ten years back, it was evident that the poor service formerly rendered was due to the uncertainty of franchise renewal caused by the agitation for municipal ownership, which resulted in making it impossible to get capital for improvements and rehabilitation of equipment. It was interesting that in a voluminous report on this problem made by Bion J. Arnold in November, 1902, there were recommended most of the features subsequently incorporated in the franchise ordinances of February, 1907. It took nearly five years to secure their adoption, but in the one and one-half years since over half the work has been carried into effect.

The main features of these ordinances were pointed out and shown to be far in advance of anything ever attempted in this line. The functions of the supervising engineers in seeing that the provisions are carried out were explained, and the organization and duties of the engineering corps described. The work done by the different branches of this corps was illustrated by considering in detail the typical methods made use of by the division on power distribution, with which the speaker is connected. Preparations of plans, securing of estimates, inspection of the work and progress reports thereon, checking of the companies' accounts and issuance of the final certificate showing proper expenditures to capital account were explained in proper sequence. The speaker then considered at length the engineering features relating to calculation of a feeder system and practical problems met in its installation.

A brief summary of the work done and the amounts expended was given. The Chicago City Railway Company has completed seventy-five miles of rehabilitated and new single track; the Chicago Railways Company sixty-six miles. The former company has laid 2,800,000 duct-feet of conduit and installed 587,000 feet of cable in fifteen months; the latter company has laid 1,260,000 duct-feet of conduit since April 1. An interesting feature in the new equipment is the use of pay-as-you-enter cars, which were successfully introduced for the first time in this country on the south side lines a year ago and which are being rapidly put in service throughout the city. To the original valuation of the surface traction properties, placed at $50,000,000 at the time of passage of the ordinances, there has been added $21,000,000, which represents approved expenditures for rehabilitation and new equipment, making the total capital account at the present time $71,000,000.

At the conclusion of Mr. Rice's address he met the members of the Branch at close range in an upper hall of the Institute and answered many questions in regard to all aspects of the rehabilitation work and particularly in regard to details of its technical features.

Los Angeles Section

This section held its regular meeting at the University of Southern California on Tuesday, November 17, 1908, with an attendance of 55. The chairman commented on the recent acquisition of new members, and with a view to maintaining the social side of the work, appointed an entertainment committee of five members. A membership committee of ten was also appointed, to assist in the campaign for new members.

The principal feature of the evening was Mr. Ed. Y. Porter's paper on "Some Notes on the Calculation of Illumination", which was well received. Mr. Manahan, city electrician, discussed this paper with reference to its application to the illumination of the streets of Los Angeles. Mr. G. H. P. Dellman referred to the artistic method of illumination of the principal business streets of the city by the use of carbon filament lamps and sanded glass globes, mounted on cast iron columns.

Mr. C. W. Koiner referred to the historical development of this branch of engineering, while Mr. Bennett went into a general analysis of colors and the fundamental principles of artificial illumination, which was accompanied by appropriate diagrams. The secretary read a facetious communication on the subject by Mr. R. J. C. Wood. Among others who participated in the discussion were Messrs. Lighthipe, Copeland, Northmore, Cunningham, Benedict Ballard, Gilmore, Bowker, Scattergood and Macdonald.

Minnesota Section

This Section held its November meeting at the Central High School, St. Paul, Minn., on the 23rd instant. The meeting was well attended. Professor B. F. Grant gave a talk on "The Development of Dynamic Flying Machines", which was illustrated by lantern slides. Mr. F. R. Cutcheon read a paper on "Tungsten Lamps."

University of Missouri Branch

This Branch held a meeting on November 20, 1908, Professor H. B. Shaw presiding, with a total attendance of 24. The Institute paper on "Electric Heating" was presented by the chairman, who outlined recent progress in this branch of engineering. Messrs. Fawks and McAdam showed a model of a new electric heater now being developed by them, and discussed the principle of its operation. Professor A. E. Flowers gave data on the comparative costs of power from different sources. Messrs. Duffy, Kleinschmidt, Mallery and others took part in the general discussion that followed.

Montana Agricultural College Branch

Instead of the regular monthly meeting the Branch visited the Bozeman transformer sub-station and street railway power house, as guests of the Madison River Power Company. This company transmits power at 46,000 volts, three-phase, from the Madison River to Bozeman, a distance of about 45 miles. The transformer station is located outside the city limits, and the street railway power house near the center of the city. The power is used for light and street railway service. Twenty-six members and visitors made the trip.

University of Nebraska Branch

This Branch held a meeting on November 4, 1908. Professor Morse read and discussed the Institute paper on "High Potential Underground Transmission", by Messrs. Junkersfeld and Schweitzer. Professor Charles L. Dean reviewed Mr. H. St. Clair Putnam's paper on "Conservation of Power Resources." Both papers were discussed by members present. The following program is arranged for the next meeting: "My First Year's Experience in Practical Electrical Work", by Clarence Johnson. Mr. I. F. Baker will review the Institute paper on "Electrical Operation of Steam Railroads". Mr. C. E. Bennett will review the Institute paper on "Alternating-Current Feeder Regulation."

NORFOLK SECTION

This Section held a meeting on Tuesday evening, November 20, 1908, at the Hotel Neddo, Mr. D. G. Stanbrough presiding, with a total attendance of 21. Preceding the meeting, a dinner was served in the hotel dining room, at which nineteen members and guests were present.

After the supper, Mr. R. R. Grant gave a talk on some advance notes from a storage battery paper, which was discussed by Messrs. W. C. Dean, C. S. Dean and D. G. Stanbrough.

The next regular meeting will be held at the Hotel Victoria. Mr. J. W. Hough will give a talk on "Transformer Testing". Preceding the meeting, a fifty-cent table d'hote dinner will be served in the hotel dining room.

OREGON AGRICULTURAL COLLEGE BRANCH

The second program meeting was held in the mechanical hall of the university, on November 9, 1908. Forty persons were present, the majority being visitors. Dr. Winegar was the speaker of the evening. The subject was "The Wireless Telegraph." Long before the speaker was through it was evident to those present that he was well informed on the subject. He gave a history of the telegraph, showing clearly the processes of its development from the earliest apparatus down to the present system. He illustrated the lecture by practical demonstrations with apparatus which he had set up in the room.

PHILADELPHIA SECTION

The December meeting of this Section was held in the Philadelphia Electric Building on the 14th instant, and was well attended, 123 being present. The following papers were presented: "The Operation and Care of Storage Batteries From the Manufacturer's Standpoint", by Hugh Lesley, "Some Experiences in the Handling of Storage Batteries, Applied to Telephone Service", by W. D. Forster. The discussion on the papers was participated in by Messrs. Hering, Lesley, Spencer, Hayward, Green, Sharer, Miller, and Day.

PITTSBURGH SECTION

The regular monthly meeting of the Pittsburgh Section was held in the Carnegie Institute lecture hall on December 8, 1908. Mr. W. Edgar Reed chairman, presided. The attendance was 110. A preliminary dinner preceded the meeting, at which 17 were present. The subject of the evening was "Some Experiences in the use of Gas Engines for Electric Power Generation", an original paper by Mr. J. R. Bibbins. Lantern slides were used to illustrate the paper. The following gentlemen took part in the discussion that ensued: Professor W. Trinks, W. E. Moore, William Hoopes, C. D. Smith, E. B. Tuttle, R. A. L. Snyder, J. G. Schroeder, W. F. Flint, E. B. McClelland, P. M. Lincoln, W. L. Waters, and D. W. Burke. The next meeting will be held on January 12, 1909, at which an original paper will be presented by Mr. William Hoopes, on electric furnaces.

PITTSFIELD SECTION

Over 100 members of the Pittsfield Section were present at its meeting November 18, 1908, and heard Dr. C. J. H. Woodbury, of Boston, speak at the Wendell Hotel, on "The Fire Hazard of Electricity." A dinner was given before the meeting, complimentary to Dr. Woodbury, and was attended by C. C. Chesney, F. R. Whittlesey, G. Faccioli, W. J. Woolridge, J. M. Gilmore, S. E. Johannesen, F. C. Geer, J. W. Johnson, and H. W. Tobey. Dr. Woodbury's talk was illustrated by lantern slides showing various methods of installation, and some of the mishaps which the underwriters rules are designed to avert.

SCHENECTADY SECTION

Owing to the severity of the weather the attendance at the December 3rd meeting of the Schenectady Section was smaller than usual, about 205 being present. Mr. E. J. Berg presided. Dr. Steinmetz delivered his fourth lecture on thermodynamics, which completed the series.

SEATTLE SECTION

Instead of the regular November meeting at the Chamber of Commerce, the Seattle Section accepted the invitation of The Home Telephone Company, which operates an automatic telephone system, to visit its exchange at Tacoma. Notwithstanding unfavorable weather conditions, a party of 40 members and guests assembled aboard the steamer Indianapolis, on Saturday, November 21, 1908, at 5 p.m. After an enjoyable dinner aboard, the party arrived at the Tacoma docks and was met by representatives of the telephone company who escorted the members to the company's exchange at 919 South D. Every arrangement had been made by the company for the entertainment of the visitors, the regular day force being in attendance to explain the workings of the automatic system of telephony. Dividing into squads, with a demonstrator for each squad, the members investigated all the details of the system and its operation, from the auxiliary gas-engine generating set to the trouble-board and toll-line switchboard. The party left Tacoma at 9:10 p.m. over the electric interurban railway.

STANFORD UNIVERSITY BRANCH

The opening meeting of this Branch was held on September 28, 1908. The publication of an engineering journal by the mechanical and electrical engineering societies was suggested. An amendment was proposed changing the date of meetings to Tuesday evening. Three new members were admitted to membership. Mr. S. B. Charters gave a talk on " Insulation Tests."

At the meeting of October 13 the amendment changing the date of meetings to Tuesday evening was voted upon and carried. A committee was appointed to confer with a committee of the mechanical engineering society concerning the proposed engineering journal. Five new members were elected. Mr. Buell described sub-station " C " of the United Gas and Electric Company of San Francisco. Mr. C. F. Elwell presented a paper on " Electric Smelting of Iron."

Another meeting was held on October 27, at which 18 members were present. Chairman North presided. The subject of the evening, " Braking Devices as Applied to Mine Hoists ", was presented by Mr. W. C. Cole.

The matter of the engineering journal was brought up again at the meeting of November 10. It was decided that the Branch would coöperate with the other societies in the publication of the journal, provided that it be representative of all the branches of engineering in the university. Mr. S. B. Dole gave a historical review of wireless communication. Mr. A. J. Gowan gave a description of Power Development on the Stanislaus River, Cal.

SYRACUSE UNIVERSITY BRANCH

The regular meeting was held Thursday evening, November 19, 1908. Mr. E. C. Sevin gave an abstract of the Institute paper on "High Potential Underground Transmission." This was followed by a general discussion of the paper by the members present.

At the meeting held December 3, 1908, Mr. R. A. Porter presented Mr. Hadaway's Institute paper on " Electric Heating," Dr. Graham and Mr. Holbrook led the discussion that followed. Nineteen members were present.

UNIVERSITY OF TEXAS BRANCH

Twenty members attended the regular meeting of this Branch on November

20, 1908. A short talk was given by Mr. H. C. Porter on " Experiences in Obtaining Vacation Work." Mr. Porter's remarks were followed with interest and brought forth some little applause. Reviews of the following Institute papers were then given by different members of the Branch: " Heating System of the Biltmore Estate," " Double-decked Steam Turbine Plant," and " Gas-Electric Power Plants." Each of the reviews was discussed by members present.

The regular December meeting was held on the 4th, with 15 members present. A paper was presented by Mr. J. A. Correll, entitled " Notes on Units of Illumination." This paper contained many interesting points concerning the different units used in photometric work, and also pointed out the way in which some of these units are often confused and misused. After a discussion of the paper, Mr. L. E. Jones gave a talk on " Railway Block Signals for a Single Track Road." Mr. Jones explained the working of the signals, by means of an enlarged diagram showing the track and various circuits. His talk was discussed at some length.

Toledo Section

The Toledo Section held its regular monthly meeting in the physics lecture room of St. John's College. Father Hillig made the address of the evening, taking as his subject ions and electrons, illustrating his talk with experiments and lantern slides. The experiments involved liquid, gaseous, and solid conductors. With liquids, changes were detected by variation of color of litmus solution; with gases, by the beautiful phenomena of violet rays and green fluorescence; and with a solid granular substance known as kryptol there was produced a convenient variable resistance. A unanimous vote of thanks was given Father Hillig for his entertaining address. After the discussion the members of the Section availed themselves of an invitation to visit the college museum where many articles of interest were seen.

Urbana Section

This Section held a meeting on November 18, 1908, in the electrical laboratory of the University of Illinois, at which Professor E. B. Paine presided. There was a total attendance of 60. Dr. Charles G. Knipp and Mr. J. M. Bryant were elected to serve on the executive committee. Professor Brooks, Messrs. Amrine, Farmer and Doyle were elected a committee on membership. The executive business being disposed of, Professor Brooks presented a report of the November meeting of the Institute, held in New York. The paper presented at that meeting, on " Electric Heating ", was then discussed by Messrs. Knipp, Bryant and Jensen. Mr. Bryant brought out the point that electric heating would give the central stations a better load-factor. Professor Paine then introduced the subject of " How to Obtain the Greatest Benefit from Engineering Periodicals." Various systems were outlined by Messrs. Crawshaw, Bryant, Amrine, Waldo, James, and Jensen, after which the meeting adjourned and refreshments were served.

Washington University Branch

On the afternoon of December 2, 1908, twelve members of this Branch made a tour of inspection of the new Soldan High School, under the guidance of Mr. C. M. Bulkley, electrical engineer for the St. Louis Public School Board. By means of blue prints Mr. Bulkley first explained the general plan of ventilating and lighting the building. He then conducted the party over the premises, pointing out the air intake windows, the wash-room, the hot-room, tempering room, and ducts leading from the fans. He also explained the arrangement of the electric feed wires so placed that the cabinets could be situated in the basement instead of disfiguring the hallways.

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UNIVERSITY OF WISCONSIN BRANCH

The University of Wisconsin Branch met at the Madison City Library Building on the evening of November 24, 1908. Mr. T. C. Burr presented a paper on "The Influence of Commercial Conditions on the Theoretical Design of Electrical Machinery." Mr. Kustermann presented an abstract of the Institute paper on "Electric Heating", by W. S. Hadaway, Jr. A discussion followed the reading of both papers.

WORCESTER POLYTECHNIC INSTITUTE BRANCH

The regular meeting of the Worcester Polytechnic Institute Branch was held November 20, 1908, in the electrical engineering lecture hall, with an attendance of 400. The lecture was in charge of Professor Joseph O. Phelon and Mr. Carl D. Knight, both of the Institute. They chose as their subject "Modern Applications of Electricity." Several incandescent lamps were shown, and were so connected to a meter that the cost of operation of any type of lamp could be read directly from the meter in cents per hour. These costs were given at the present rate for electric light in Worcester. The lamps shown included one used about 15 years ago, also the regular carbon lamp, the metalized filament lamp, the Nernst lamp, the tantalum lamp, and the tungsten lamp. The quality of light from these lamps was also shown by comparing different colored papers in the various lights. The different types of arcs were next shown. First the regular carbon arc was thrown on a screen and the difference in the arc with direct and alternating current was shown. The magnetite arc was next shown, and then the flaming arc. Lastly the mercury vapor lamp was shown. Electric welding was next demonstrated, and an electric water-forge was shown in operation. Several electric novelties were also exhibited. After the lecture the audience adjourned to the general laboratory where six large tables were amply supplied with doughnuts and cheese, and sweet cider was brought to the individual tables from a barrel hung from the crane-hook. In the south gallery of the laboratory there was arranged an exhibition of electrical household appliances. With each piece of apparatus was a card, stating the initial cost of the appliance, and the operating expense per hour at the present price of electricity in Worcester. Each piece of apparatus was in actual operation so that every one could see how it acted and just what it would accomplish. Members of the electrical department were present to answer any questions that might come up. The automatic recording apparatus on the test car was in operation and Mr. Albert T. Childs, who has done much of the designing and construction of this novel piece of apparatus, was present to answer any questions and explain any points that might be brought up. The "Tech Orchestra" very kindly furnished music in the laboratory, which added much to the pleasure of the evening. This was ladies night and many friends of the members were present.

Massachusetts Institute of Technology

There are now 215 graduate students studying at the Massachusetts Institute of Technology, and a large number of the young men studying electrical engineering at the Institute come from among these graduate students. Many of these students in the electrical engineering course have heretofore pursued a course in arts or a course in general science and are spending two or three years in completing the electrical engineering course. Others have graduated from other engineering schools and are spending from one to two years in study to get the Institute's baccalaureate degree in electrical engineering. A few are pursuing advanced study and research for the purpose of obtaining the higher degrees of master of science in electrical engineering or doctor of engineering.

Personal

Mr. George A. Burnham has been transferred from the construction department to the engineering staff at the Boston office of the General Electric Company.

The position of commercial engineer has been recently created by the Allis-Chalmers Company, of Milwaukee, and Mr. Frank G. Bolles has been appointed to that place.

Mr. G. M. Dyott, engineer, who formerly had headquarters at Pittsburgh, is now located in New York, with offices at the Hudson Terminal Building, 50 Church Street, New York City.

Mr. J. H. Waugh has opened an office in 212 Ferguson Building, Pittsburgh, Pa., where he is doing a general sales agents business in the electrical line, representing a number of companies.

Mr. L. R. Nichols, formerly with the Hudson River Electric Power Company of Albany, N. Y., has accepted a position as electrical engineer with the Union Bag & Paper Company, Sandy Hill, N. Y.

Mr. R. S. Flesheim, for over four years connected with the Allis-Chalmers Company at their Bullock works and Cincinnati district office, has recently been transferred to the Detroit office of the same company.

Mr. L. L. Hirsch has severed his connection with the Westinghouse Electric & Manufacturing Company, to take charge of the engineering department of the Interstate Electric Company, New Orleans, La.

Mr. H. C. L. Gooding, formerly electrician in charge, department of ordnance, Brooklyn Navy Yard, N. Y., has located at Cananea, Son. Mexico, as chief electrician, Cananea Consolidated Copper Companies.

Mr. J. P. Mallett recently resigned his position as chief engineer of the Northern Electric Manufacturing Company at Madison, Wis., and accepted a position with the Diehl Manufacturing Company at Elizabethport, N. J.

Jesse M. Smith, consulting electrical and mechanical engineer, 220 Broadway, New York City, a charter member of the Institute, was elected president of the American Society of Mechanical Engineers at the annual meeting held December 8–11, 1908.

Mr. O. D. Mudgett, formerly connected with the Boston office of the Westinghouse Electric & Manufacturing Company, as erecting engineer, has accepted the position of assistant superintendent of The Belfast Gas and Electric Company, Belfast, Maine.

Mr. L. P. Perry has resigned his position as assistant manager of the Fries Manufacturing & Power Company of Winston-Salem, N. C., and is now promoting an electrical invention that is used in connection with moving picture theatres, with headquarters at Warren, Ohio.

Mr. O. M. Roberts, who has for some time been superintendent of the public works at Orangeburg, S. C., has resigned his position, and has taken up electrical engineering and contracting work at Athens, Ga., having associated himself with the Athens Engineering Company of that place.

Mr. John Mustard, for the past 15 years district manager of the Philadelphia office of the Wagner Electric Manufacturing Company, has been appointed assistant manager of sales for the East, including Pittsburgh, and the territory east of Pittsburgh, with headquarters in Philadelphia.

Mr. Karl B. Kumpe, for the past two years locating engineer for the Chicago, Milwaukee & St. Paul Railway Company's Pacific extension, has accepted a position with the Port Angeles Railway & Terminal Company, in charge of the location of their line from Port Angeles to Port Ludlow, a distance of sixty miles.

Mr. William Corin until lately City Electrical Engineer of Launceston, Tasmania, and subsequently in private practice as consulting engineer, has recently been appointed electrical engineer to the Department of Public Works and consulting electrical engineer to the Department of Mines, New South Wales, with headquarters at Sydney.

Mr. J. A. Wells, formerly chief engineer with the Augusta-Aiken Railway & Electric Company, of Augusta, which position he resigned to take up the development of hydroelectric plant for himself and others and to organize and incorporate the Wofford Shoals Light & Power Company, at Cornelia, Ga., is now the editor of the *Southern Electrician*, Atlanta, Ga.

Mr. William G. B. Euler is handling the installation of the electrical equipment at the 20,000-k.w. 104,000-volt hydroelectric station of the Union Construction Company, at Villicita, Cal. Mr. Euler is representing the General Electric Company on this work. Previously to this transfer he was connected with the Los Angeles office of the General Electric Company.

Mr. H. L. Kirker, who was the resident engineer of the Westinghouse Electric & Manufacturing Company on the St. Clair Tunnel electrification from the commencement of the work until the official inauguration of the new service, November 12, 1908, is for the present engaged in the railway division of the engineering department of the same company, at the East Pittsburgh works.

Mr. Norman P. F. Death, lately with Mr. C. H. Mitchell, consulting engineer, and Mr. Lionel Watson, until recently in charge of the electrical department of the Dominion Automobile Company, has associated himself with these gentlemen and opened an office and factory at 25 Jarvis Street, Toronto, Canada, where they will conduct a business as electrical and illuminating engineers and manufacturers of electric signs.

Mr. H. B. Corning, formerly with the Seattle Electric Company, Seattle, Washington, has succeeded Mr. Will N. Parsons as superintendent of the Mexican Light & Power Company's suburban districts. Mr. Parsons was for several years general manager and chief engineer of Cia. Electrica Robert, of Mexico City, which company was absorbed by the Mexican Light & Power Company. Mr. Parsons is now located in France.

Resolutions on the Death of Frederick A. C. Perrine, Member A.I.E.E.*

Whereas, Frederick Auten Combs Perrine, as a graduate student at Princeton University, as electrician of the United States Electric Light Company, as manager for John A. Roebling's Sons Company, as treasurer of the Germania Electric Company, as chief engineer of the Standard Electric Company, as president of the Stanley Electric Manufacturing Company, and as professor of electrical engineering in Leland Stanford, Jr. University, was of great influence in raising the standard and in extending the scope of the electrical engineering profession, and

Whereas, he, as a Director and as a committeeman of the American Institute of Electrical Engineers, heartily participated in its activities, thereby extending its usefulness, it is hereby

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*Adopted at a meeting of the Board of Directors, held on December 11, 1908.

Resolved: That the Board of Directors of this Institute considers that his death, on October 20, 1908, has deprived the Institute of a much valued member and the electrical engineering profession of an active and resourceful worker, and, it is further

Resolved: That these resolutions be spread upon the minutes of this meeting, that they be printed in the PROCEEDINGS, and that a copy of them be sent to Mrs. Perrine.

Ampere Memorial Tablet

A bronze tablet, of beautiful design, in honor of the memory of Andre-Marie Ampere was unveiled by Ambassador Jules J. Jusserand at Ampere, New Jersey, on Thursday, December 3, 1907, in the presence of many members of the Institute, and distinguished citizens of New York and New Jersey, invited guests of the Crocker-Wheeler Company. The tablet was presented to the Lackawanna Railroad by Dr. Schuyler Skaats Wheeler, past president of the Institute and president of the Crocker-Wheeler Company, who in his address paid a well deserved tribute to the work of the celebrated French scientist. The gift was accepted by vice-president Caldwell of the Lackawanna Railroad, who expressed his hearty appreciation of the cordial relations existing between the railroad and the manufacturing company which had founded the leading industry of Ampere. After unveiling the tablet, Mr. Jusserand gave an eloquent address, giving most interesting details of the life of Ampere, who, like the speaker, was a native of Lyons, France. The tablet has been placed on the wall of the waiting room of the artistic and substantial Ampere station just completed. After the ceremony the guests reassembled in Dr. Wheeler's suite of offices opposite the station where an elegant collation was served. Among the members of the Institute present were past presidents Wheeler, Martin and Crocker, past vice-presidents and managers Pupin, Sever and Dunn, Secretary Pope and Messrs. Arendt, Chandler, Gilder and Petty.

January Meeting A. S. M. E.

The next monthly meeting of The American Society of Mechanical Engineers will be held in the Engineers' Building on Tuesday evening, January 12, 1909. Carl G. Barth of Philadelphia will present a paper on " The Transmission of Power by Leather Belting," illustrated by lantern slides. It will be a comprehensive summing up of the theory and practice of belting in which conclusions are drawn from the work of Lewis, Bancroft, Bird, and others, who have made experiments upon the transmission of power by belting. Valuable charts have been prepared by the author for the solution of belting problems.

Mr. Barth's long experience in the scientific running of machine tools, in connection with the introduction of improved shop methods, has shown the need of definite data for the application of belting to machinery, and led to the development of the results contained in his paper. His data have been applied to belting in different plants for many years, giving an unusual opportunity to study the problem in great detail.

Arts Subjects for Engineers at Cornell

The report of the president of The Cornell University for the year 1907-1908 contains the following items of interest relating to the proposed changes at that university in the course of instruction for engineers:

" In considering the recommendations in the president's report for 1906-1907 regarding the importance for students in the professional schools of English, history, economics and other subjects taught in this college, the Faculties of Civil Engineering and Mechanical Engineering were led to adopt five year courses, each course including over 70 hours in Arts and Sciences and at least 30 hours in literary and social studies.

These courses are to be alternative courses, the former four year courses being also retained for the present.

Their action was made of especial interest to the Faculty of Arts and Sciences by virtue of the fact that the Engineering Faculties proposed to have the students entering the five year courses enrolled for two years in the College of Arts and Sciences and for the remaining three years in Civil or Mechanical Engineering. This proposal was referred by the Board of Trustees to this Faculty. It was not possible for the Committee on Educational Policy, to whom the courses were referred, to give adequate consideration to the matter before the close of the academic year, so that no final report was submitted to the Faculty but a report will be made and a definite policy decided upon early next year.

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A change in the sequence of the shop courses is proposed and will be made next year. The work in the foundry and forge shop, hitherto given to sophomores, will be given to freshmen and the pattern making will be transferred from the first to the second year. It is believed that the student who has used patterns in the foundry for the producing of castings, will be able to accomplish more in making patterns because of a better understanding of their purpose.

It is also proposed to modify somewhat the instruction in the blacksmith shop. The growth of the electrical manufacturing industry has necessitated the introduction of many new processes for the cold-working of metal and it is hoped that it may soon be possible to introduce machines which have been developed in response to this need. All of the essentials in the teaching of hand forging will, however, be retained."

Nominations

For the purpose of giving information to the membership in connection with future nominations for officers of the Institute, after the distribution of the nomination forms, in February, the following by-law was adopted by the Board of Directors November 13, 1908:

> Sec. 18. For the guidance of members in the selection of nominees for the annual election there shall be published in the January and February Proceedings, each year, a summary of the nomination votes of the preceding year containing the names of all persons having received at least three per cent of the entire number of nomination votes cast, and also the names of all directors not included in this list and of ex-Vice-Presidents and Managers who have held office at any time during the preceding five years

In compliance with this by-law the following list has been compiled:

General Proposal List, April 1908

FOR PRESIDENT

L. A. Ferguson	579
Ralph D. Mershon	93
A. H. Armstrong	48
L. B. Stillwell	42

FOR VICE-PRESIDENTS

C. L. Edgar	318
C. C. Chesney	289
Calvert Townley	255
B. Gherardi	192
E. J. Berg	132
A. S. Langsdorf	71
J. J. Carty	48
P. Junkersfeld	44
Ralph D. Mershon	42

FOR MANAGERS

D. B. Rushmore	553
H. E. Clifford	301
H. B. Smith	204
C. W. Stone	160
J. G. Wray	135
A. W. Berresford	126
F. S. Hunting	74
W. G. Carlton	70
N. W. Storer	58
W. S. Rugg	45
H. W. Fisher	41
W. S. Murray	40

FOR TREASURER

George A. Hamilton	978

FOR SECRETARY

Ralph W. Pope	1082

[Names of members who received less than 3% of the entire number of votes cast have been omitted from the above list in accordance with section 18 of the by-laws].

PRESENT DIRECTORS NOT INCLUDED IN ABOVE GROUPS

Samuel Sheldon
Henry G. Stott
James G. White
W. C. L. Eglin
A. M. Schoen
Paul M. Lincoln
Paul Spencer
Morgan Brooks
Harold W. Buck
Percy H. Thomas
Benjamin G. Lamme

EX-VICE-PRESIDENTS AND MANAGERS WHO HAVE HELD OFFICE DURING THE LAST FIVE YEARS NOT INCLUDED IN ABOVE GROUPS

John W. Lieb, Jr.
R. T. E. Lozier
Schuyler S. Wheeler
W. S. Barstow
Charles L. Clarke
Calvin W. Rice
W. E. Goldsborough
Samuel Reber
George F. Sever
Gano Dunn
C. O. Mailloux
Charles A. Terry.
Townsend Wolcott
Frank G. Baum
Charles L. Edgar
H. H. Humphrey

1909 Year Book

A new edition of the Institute Year-Book will be ready for distribution early in January. The contents include: Lists of Officers, Committees, Sections and Branches; Alphabetical and Geographical Lists of Members of all Grades; Constitution, By-Laws, Report of Board of Directors for year ending April 30, 1908, and the Standardization Rules; also general information for the use of non-members, regarding the objects, scope and work of the Institute.

As practically the entire contents of the book excepting the revised lists of members, have appeared in the PROCEEDINGS copies will not be mailed to the membership, and the volume will be used principally in connection with the work of the Increase of Membership Committee. Any Member or Associate may, however, obtain a copy upon application to the secretary's office, by mail or in person.

Library Accessions

The following volumes have been received and placed in the Library of the Institute:

Gift of Park Benjamin

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Evidence for Complainants. Vol. 2 and 4. Harrisburg, 1884.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Defendants' brief.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Defendant's Sur-Rejoinder.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Defendant's case, Vol. 1 and 2.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Defendant's Sur-Rebutting Testimony. Harrisburg, 1884.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Complainant's Exhibits. Vol. 2. Boston, 1882.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Defendant's brief.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Complainant's evidence. Part 1.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Defendant's book of exhibits.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Complainant's case. Vol. 1. Parts 1 and 2 and Vol. 2.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company.

Abstracts of testimony. Boston, 1884.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Brief for Complainants on Final Hearing. Boston, 1884.

United States Circuit Court. American Bell Telephone Company and The People's Telephone Company. Complainant's Closing Testimony.

United States Circuit Court. Amos E. Dolbear and American Bell Telephone Company. Boston, 1887.

United States Patent Office. Voelker v. Gray *et al.* Interference. Subject-matter: " Telephones."

United States Department of the Interior. Argument of Mr. J. J. Sorrow for Mr. Bell and the Bell Co.

United States Patent Office. Before the commissioner of patents on appeal. *In re* application of Daniel Drawbaugh, filed Oct. 26, 1880.

United States Circuit Court. The Am. Bell Tel. Co. *et al.* v. The People's Tel. Co. *et al.* Arguments of Hon. Lysander Hill and Hon. Geo. F. Edmunds for the defendants. 1884.

United States Circuit Court. American Bell Tel. Co. *et al* v. The People's Tel. Co. *et al.* Argument of J. J. Sorrow Esq., for complainants. 1884.

United States Supreme Court. The People's Tel. Co. *et al* v. The Am. Bell Tel. Co. *et al.* Arguments of Lysander Hill, Esq.

United States Circuit Court. The Am. Bell Co. *et al* v. The Long Distance Tel. Co. *et al.* Bill of Complaint.

Book of descriptive plates of the Bell Telephone Co.

Gift of Electric Railway Journal

Arbeiterwohlfort. Katalog der ständigen ausstellung für Arbeiter-wohlfort. Charlottenburg.

Berliner Strassenbahn, Grosse. Geschäftsbericht für 1906.

Tramways Brusselles. L'usine centrale et les installations éléctriques. 1903.

Canada. Dept. of Railways and Canals. Annual report of the Dept. of railways and canals for 1905.

Cape Electric Tramways, Ltd. Report and accounts, June 30, 1906.

Central South African, Transvaal, and Orange River Colonies, Railways. Chief Traffic Manager's Report on an official visit to international ry. Congress Washington, D. C,. U. S. A. Feb.-Aug., 1905.

Chicago Street Railways. Street Railways, 1905.

Christchurch Tramway Board. Abstract Statement of Revenues and Expenditures. 1905-1906.

Compagnie de l'industries éléctrique et Mecanique (Geneva). Bulletin No. 2. Janvier 1903.

Compagnie du chemins de fer de Paris à Orléans. Exposition Universelles de 1900. Notice sur les. I. Installations éléctriques. II. Locomotives éléctriques. Paris, 1900.

Compagnie Française pour l'exploritation des Procédés Thomson-Houston. Assemblie Generale Ordanaire du 22 Mars 1901 (dupl.).

Compagnie Ottomane Par Actions Tramways de Salonique, 16th exercice sociale. 1907.

Connett, A. N. (Inst. Mech. Eng. London Proc.). Combined Trolley and Conduit Tramway System.

Dumas, M. P. Essais de Traction éléctrique entre les gares de la Motte-les-Bains et la Motte-d'Availlons.

Edison Co. Map of Manhattan and Bronx, showing Edison System 1904.

England Tramway and Light Railway Association. Official circular. July 1908.

Exploration Co., Ltd. Notes on the Central London Railway. 1895.

Ford, Bacon and Davis. Northeastern New Jersey and Staten Island Street Railway Systems. Map Nov. 10, 1903.

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PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly at 33 W. 39th St., New York, under the supervision of

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Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month.

Vol. XXVIII **February, 1909** No. 2

February Meeting A. I. E. E.

The two hundred and thirty-fourth meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineer's Building, 33 West Thirty-ninth Street, New York, on Friday, February 19, 1909, at 8 o'clock p.m. Dr. Charles P. Steinmetz, past-president of the Institute and consulting engineer of the General Electric Company, Schenectady, N. Y., will present a paper entitled, "Prime Movers." The paper is printed in this issue of the PROCEEDINGS, pages 135–156. The February meeting will be held on the third instead of the second Friday, as the second Friday, February 12, falls on a holiday, Lincoln's birthday.

Election of Officers of the A. I. E. E.

In accordance with Article VI, Sec. 30, of the Constitution, during the first week in February, 1909, there will be mailed or delivered to each Member and Associate a list of all Members and Associates, together with a form showing the offices to be filled at the annual election in May.

As provided for in Art. V. Sec. 25 of the Constitution, at the annual meeting of the Institute to be held in New York, in May, 1909, there shall be elected a president, three vice-presidents, four managers, a secretary, and a treasurer.

Nominations

For the purpose of giving information to the membership in connection with future nominations for officers of the Institute, after the distribution of the nomination forms, in February, the following by-law was adopted by the Board of Directors November 13, 1908:

> SEC. 18. For the guidance of members in the selection of nominees for the annual election there shall be published in the January and February PROCEEDINGS, each year a summary of the nomination votes of the preceding year containing the names of all persons having received at least three per cent of the entire number of nomination votes cast, and also the names of all directors not included in this list and of ex-Vice-Presidents and Managers who have held office at any time during the preceding five years.

In compliance with this by-law the following list has been compiled:

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A. H. Armstrong	48
L. B. Stillwell	42

FOR VICE-PRESIDENTS

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C. C. Chesney	289
Calvert Townley	255
B. Gherardi	192
E. J. Berg	132
A. S. Langsdorf	71
J. J. Carty	48
P. Junkersfeld	44
Ralph D. Mershon	42

FOR MANAGERS

D. B. Rushmore	553
H. E. Clifford	301
H. B. Smith	204
C. W. Stone	160
J. G. Wray	135
A. W. Berresford	126
F. S. Hunting	74
W. G. Carlton	70
N. W. Storer	58
W. S. Rugg	45
H. W. Fisher	41
W. S. Murray	40

FOR TREASURER

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FOR SECRETARY

Ralph W. Pope	1082

[Names of members who received less than 3% of the entire number of votes cast have been omitted from the above list in accordance with section 18 of the by-laws].

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Minutes of January Meeting of the Institute

The two hundred and thirty-third regular meeting of the American Institute of Electrical Engineers, was held in the auditorium of the Engineers' Building, 33 West thirty-ninth street, New York, Friday, January 8, 1909. President Ferguson called the meeting to order at 8:00 p.m.

The secretary announced that at the meeting of the Board of Directors held during the afternoon there were 114 Associates elected, as follows:

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Camp, Eugene Vernon, Fellow in Ry. Electrical Engineering, University of Illinois; res., 611 West Green St., Urbana, Ill.

Carpenter, L. M., Electrical Engineer, Schuylkill Railway Co., Girardville, Pa.

Carr, Charles Clement, Student Apprentice, Western Electric Co.; res., 441 Englewood Ave., Chicago, Ill.

Carter, Robert Anderson, Jr., Cadet Engineer, Westchester Lighting Co., New Rochelle, N. Y.

Christy, John Burson, Construction Dept., The Connecticut Co., New Haven, Conn.

Couch, Herbert B., Salesman, The Dean Electric Co., Elyria, Ohio; res., Lincoln, Neb.

Craig, Ira Lynn, Meter Test Dept., Citizens Gas & Electric Co.; res., 217 E. 10th St., Waterloo, Iowa.

Creedy, Frederick, Engineer, Westinghouse E. & Mfg. Co., Pittsburg; res., 831 Holland Ave., Wilkinsburg, Pa.

Cunningham, John Atkinson, Asst. General Manager, Saginaw-Bay City Railway & Light Co., Bay City, Mich.

Dapprich, Carl Emil Louis, Electrical Engineer, American Electric Constr. Co., 416 Fisher Bldg.; res., 4811 Champlain Ave., Chicago, Ill.

Davis, Ernest H., General Manager, Edison Electric Illuminating Co., Williamsport, Pa.

Elkas, Isaac, Agent, Sprague Electric Co., 315 Chemical Building, St. Louis, Mo.

Engler, John, Student, Pratt Institute res., 190 Washington Ave., Brooklyn, N. Y.

Ellis, Isaac Kingsley, Student, University of Vermont, Burlington, Vt.

Ellis, John William, Testing Engineer, General Electric Co.; res., 791 State St., Schenectady, N. Y.

Fagberg, Charles John, Electrical Dept., L. A. Aqueduct; res., 525 Ruth Ave., Los Angeles, Cal.

Fay, Frank Homer, Asst. to Special Agent American Tel. & Tel. Co., 15 Dey St.; res., 24 West 32nd St., New York City.

Forster, William Dickson, Asst. Engineer, Bell Telephone Co. of Pa.; res., 3729 Locust St., Phila., Pa.

Fottler, Jacob Alger, Instructor in Electrical Engineering, Rhode Island College of A. & M. A.; res., Kingston, R. I.

Getts, Frank Elmer, Engineer, General Electric Co., Monadnock Building, Chicago, Ill.

Gleim, Thomas Russel, Asst. Engineer, Bell Telephone Co. of Pa.; res., Landsdowne, Pa.

Gochicoa, Edward O., Supt., Sultepec Electric Light & Power Co., Temascaltepec, Mexico.

Gregson, Edward Jesse, Inspector in Switchboard Dept., General Electric Co.; res., 228 Liberty St., Schenectady, N. Y.

Griest, Thomas Haines, Asst. Engineer, Bell Telephone Co. of Pa.; res., 2231 Wallace St., Phila, Pa.

Hangan, Charles Morino, Supt. Substation Construction, Sanitary District of Chicago; res., 1713 Deming St., Chicago, Ill.

Hansell, Charles Earl, Foreman, Testing Laboratories, Duncan Electrical Mfg. Co.; res., 215 Littleton St., W. Lafayette, Ind.

Hanson, Frank Herbert, Asst. Field Inspector, Railroad and Tax Commission; res., 317 N. Patterson St., Madison, Wis.

Harrison, Arthur Waugh, Electrician, Llewellyn Iron Works; res., 338 West 30th St., Los Angeles, Cal.

Harrison, Charles Edward, Chief Equipment Inspector, American Tel. & Tel. Co., 1302 Candler Building, Atlanta, Ga.

Haskell, Frank Edward, Student, General Electric Co.; res., 68 Warren St., West Lynn, Mass.

Hazeltine, Louis Alan, Instructor in Electrical Engineering, Stevens Institute; res., 529 Garden St., Hoboken N. J.

HEINEMANN, GEORGE, General Electrical Contractor; res., 1226 N. Seventh St., Phila., Pa.

HIGSON, C. R., Instructor in Electrical Engineering, University of Wisconsin, Madison, Wis.

HICKMAN, CHARLES IRVIN, Repairman, Chicago Telephone Co.; res., 265 La Salle Ave., Chicago, Ill.

HOEFER, ELMER GEORGE, Professor of Mechanical Engineering, University of Wyoming, Laramie, Wyoming.

HUTCHINGS, O. H., Supt., Dayton Lighting Co.; res., 44 Riverdale St., Dayton, Ohio.

HUTCHINSON, HOWARD D., Agent, Small Motor Dept., General Electric Co.; res., 71 East 47th St., Chicago, Ill.

JONES, THOMAS NORMAN, JR., Supt., Richmond & Chesapeake Ry. Co.; res., 910 West Grace St., Richmond, Va.

KEEL, CHARLES HERBERT, Tester, General Electric Co.; res., 17 Barrett St., Schenectady, N. Y.

KILPATRICK, JAMES LESTER, Bell Telephone Co. of Pa.; res., 5133 Baltimore Ave., Phila, Pa.

KING, JOHN RUSSELL, Student Engineer in Testing Dept., General Electric Co., Schenectady, N. Y.

LA RUE, JAMES MALCOM, Engineering Assistant, New York Tel. & N. Y. & N. J. Tel. Co.; 15 Dey St., New York City; res., 14 Boulevard, Summit, N.J.

LEWIS, AUGUSTUS PERCIVAL, Electrical Engineer, Chicago City Ry. Co.; res., 221 East 54th St., Chicago, Ill.

LUNT, RAYMOND LOUIS, Engineer, The Electric Storage Battery Co.; res., 2047 Ontario St., Phila., Pa.

McKENZIE, FRANK WILLIAM, Apprentice Engineer, Massillon Electric & Gas Co., Massillon, Ohio.

McLAIN, ROBERT HENRY, Electrical Tester, General Electric Co.; res., 17 Barrett St., Schenectady, N. Y.

McWHORTER, W. A., Expert, Elec. Ry. Dept., Galena-Signal Oil Co.; res., 1012 Central Ave., Birmingham, Ala.

MANWARING, ALBERT H., Electrical Engineer, Philadelphia Electric Co.; res., 2033 N. 33rd St., Phila., Pa.

MARTIN, KINGSLEY GOULD, Tester, New York Edison Co., 55 Duane St.; res., 40 Morningside Ave., New York City.

MASTICK, REUBEN WOOD, JR., Engineer, Pacific Tel. & Tel. Co.; res., 1830 Walnut, Berkeley, Cal.

MILLER, MORTON O., Supt. of Light, Heat & Power, Foster Bros. Mfg. Co.; res., 69 Oswego St., Utica, N. Y.

MOURADIAN, H., Asst. to Engineer, Bell Telephone Company of Pa.; res., 1434 Pine St., Phila., Pa.

MULLIGAN, BARRY, President, Electric Construction and Advertising Co.; res., 909 Rebecca Ave., Wilkinsburg, Pa.

NATHAN, EUGENE J., Asst. Engineer, Bell Telephone Company of Pa.; res., 468 Franklin St., Phila, Pa.

PALMER, GUY HAGERMAN, Asst. Engineer, The Telluride Power Co., Telluride, Colo.

PEASE, MAURICE HENRY, Soliciter, El Paso Electrical Ry. Company, El Paso, Texas.

PETERSON, GEORGE FREDERIC, Electrical Dept., Indiana Steel Co., Gary; res., Miller, Ind.

PIPER, CHARLES MERRITT, Wireman, Westinghouse Electric & Mfg. Co.; res., 517 North Charles St., Baltimore, Md.

POLLARD, WALTER SAMUEL, Electrical Engineer, 733 Samson St.; res., 1501 No. Franklin St., Phila., Pa.

PORTER, EDWIN H., Sales Engineer, Ft. Wayne Electric Works; 415 N. A. Building, Phila, Pa.

RAMSEY, GEORGE WILLIAM, Third Asst. Examiner, United States Patent Office, Washington, D. C.

RANDOLPH, ROBERT JOHN, JR., Sales Engineer, Crocker-Wheeler Co., Ampere, N. J.; res., 109 West 45th St., New York City.

REED, FRANKLIN HOLMES, Editor *Telephony*, Chicago, Ill.

RICHARDS, LEWIS C., Engineer, Westinghouse Electric & Mfg. Co., New York City; res., 7 Sickles Ave., New Rochelle, N. Y.

Roffee, Barton E., Motor Inspector, Commonwealth Edison Co., 139 Adams St.; res., 7541 Emerald Ave., Chicago, Ill.

Rose, William Henry, First Lieutenant and Instructor in E. & M. E., Engineer School, Washington Barracks, D. C.

Roszel, Richard Julian, Asst. Engineer, Bell Telephone Co. of Pa.; res., 2111 N. 12th St., Phil., Pa.

Rowat, Frank Thomas, Meter Tester, Des Moines Electric Co.; res., 1101 Walker St., Des Moines, Iowa.

Russell, Robert Elmer, Commercial Engineer, General Electric Company, Schenectady, N. Y.

Schiller, Walter R., General Manager Electric Garage Company, Utica, N. Y.

Schlombs, Willi, Engineer, Siemens-Schuckert Werke, City of Mexico, Mexico.

Seibel, Charles William, Electrical Inspector, North Shore Electric Co.; res., 208 Clinton Ave., Oak Park, Ill.

Short, Andrew Jay, Engineer, Rome Gas, Electric Light & Power Co., Rome, N. Y.

Silberberg, Leon, Construction Dept., Consolidated Gas, Electric Light & Power Co.; res., Central Y. M. C. A., Baltimore, Md.

Simpson, Tennyson Wendell, Asst. to Supt. of Construction, Lowell Electric Light Corporation, Lowell, Mass.

Sinclair, Henry H., 803 Central Building, Los Angeles, Cal.; res., Pasadena, Cal.

Skacelik, Joseph, Draughtsman, Hydro-Electric Power Commission of Ontario; res., 196 John St., Toronto, Ont.

Slocum, Thaddeus Newell, Asst. Electrical Engineer, Grays Harbor Railway & Light Co.; res., 109 N. Broadway, Aberdeen, Washington.

Slutz, Charles Samuel, Central Station Operator, Pacific Electric Ry. Co.; res., 2636 E. 2d St., Los Angeles, Cal.

Spencer, Frederick Asher, Post Graduate Student, Worcester Polytechnic Institute; res., 4 Hackfeld Rd., Worcester, Mass.

Sprout, Sidney, Consulting Engineer, Crocker Building, San Francisco, Cal.

Sturrock, Andrew Guy, Supt. and Electrical Engineer, Aguascalientes Electric Light & Power Co., Aguascalientes, Mexico.

Sutherland, James Alfred, District Wire Chief, Hudson River (Bell) Telephone Co.; res., 29 York Ave., Saratoga Springs, N. Y.

Talbot, Emmett Dailey, Wire Chief, Inter-Ocean Telephone & Telegraph Co., Buffalo; res., Bath, N. Y.

Thorp, I. Jay, Division Plant Superintendent, N. Y. & N. J. Telephone Co.; res., 416 Putnam Ave., Brooklyn, N.Y.

Throop, Francis W., Power House Supt., Dominion Power & Transmission Co., Power Glen, Ont.; res., Niagara Falls, N. Y.

Twiggs, John David, Jr., Supt., Canal & Water Works, Augusta, Ga.

Van Winckle, Oliver Blake, Traveling Electrical Inspector, Underwriters Association; res., 65 Lewis St., Toronto, Ont.

Vinson, Albert Wilkinson, Engineer, Cutler-Hammer Mfg. Co., San Francisco; res., 1643 Walnut St., Berkeley, Cal.

Volz, Philip, Consulting Electrical Engineer, 800 Broad St.; res., 49 Nelson Place, Newark, N. J.

Walton, James Arthur, Asst. to Electrical Engineer, Consolidated Gas, Electric Light & Power Co.; res., 621 Paul St., Baltimore, Md.

Walton, John Calloway, Traveling Representative, The B. R. Elec. & Tel. Mfg. Co.; res., Oklahoma City, Okla.

Walz, George Jack, Asst. Electrical Engineer, The Pennsylvania Steel Co.; res., Steelton, Pa.

Waters, Granville Avery, Instructor in Drawing, Washington University; res., 4142 West Pine Boulevard, St. Louis, Mo.

WELLER, FRANCIS MARSHALL, Electrical Tester, General Electric Company; res., 17 Barrett St., Schenectady, N. Y.

WHITSON, VILIE DOW, Electrician, with H. D. Murdock, Scottsburg, Ind.; res., Seymour, Ind.

WISCHMEYER, HENRY WINTER, Draftsman, Louisville Railway Co., Louisville, Ky.

WOODARD, ARTHUR VALENTINE, Student and Electrical Workman, Stanford University, Cal.

WOODBURY, FRED P., Electrical Engineer, Erecting Dept., Westinghouse Electric & Mfg. Co.; res., 50 Convent Ave., New York City.

WOODRING, FREDERICK KUHN, Manager, Titusville, Electric Light & Power Co., Titusville, Pa.

WRIGHT, ERNEST ALEX, Commercial Estimating Engineer, Allis-Chalmers Co.; res., 459 64th Ave., West Allis, Wis.

YOUNG, JOHN, Electrical Engineer, Electro Metals, Ltd., Welland, Ont.

The secretary announced further that the following Associates were transferred to the grade of Member:

REMIGIO JIMENEZ, Havana Gas & Electric Co., Havana, Cuba.

SAMUEL LINDZEY NICHOLSON, Manager Industrial & Power Department, Westinghouse Electric & Manufacturing Company, Pittsburg, Pa.

WILLARD GILBERT CARLTON, Superintendent of Power, Electric Division, Grand Central Station, New York.

SEVERN D. SPRONG, Assistant Electrical Engineer, United Electric Light & Power Company, 1170 Broadway, New York City.

GEORGE W. PATTERSON, Professor of Electrical Engineering, University of Michigan, Ann Arbor, Michigan.

The secretary read a communication from the chairman of the House Committee, requesting members not to smoke in the auditorium.

Professor Elihu Thomson, past-president of the Institute and electrician of the General Electric Company of West Lynn, Mass., then presented a paper entitled: "Conditions Affecting Stability in Electric Lighting Circuits." The paper was discussed by Messrs. A. E. Kennelly, Alex Dow, E. W. Rice, Jr., Dugald C. Jackson, C. M. Green, John B. Taylor, C. P. Steinmetz, and Elihu Thomson.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before March 1, 1909.

8182 Carr, Frank, Ogden, Utah.
8183 Buckman, Wm. Drayton, Phila., Pa.
8184 Demming, R. O., Germantown, Pa.
8185 Hays, D. S., San Francisco, Cal.
8186 Henry, Edw. Newton, N. Y. C.
8187 Schmidt, S. H., Perth Amboy, N. J.
8188 Totten, A. I., Schenectady, N. Y.
8189 Handy, Wm. W., Baltimore, Md.
8190 Knowlen, J. F., New Decatur, Ala.
8191 Bagley, Francis H., Swissvale, Pa.
8192 Wheelock, R. B., Omaha, Neb.
8193 Morsman, Frank S., Omaha, Neb.
8194 Makino, Kengo, Ithaca, N. Y.
8195 Lewis, H. B., Redwood City, Cal.
8196 Kelly, Alfred S., Omaha, Neb.
8197 Gagen, James M., New York City.
8198 Fair, R. Harvey, Omaha, Neb.
8199 Evarts, H. Chester, Omaha, Neb.
8200 Baruch, S. N., Oakland, Cal.
8201 Savage, W. C. Schenectady, N. Y.
8202 Stone, P. Edwards, Chicago, Ill.
8203 Hammond, J. F., Prince Bay, S. I.
8204 English, E. F., Jersey City, N. J.
8205 May, A. G., Srinagar, Kashmir, India.
8206 Rollins, E. B., Tuft's College, Mass.
8207 Merwin, Wm. C., Youngstown, O.
8208 Talbott, Chas., Chicago, Ill.
8209 Huntington, R. J., Los Angeles, Cal.
8210 Ford, R. Henry, Madison, Wis.
8211 Baer, Carl A., Harrisburg, Pa.
8212 Sparks, H. H., Junction City, Kans.
8213 Hamilton, Fred G., Visalia, Cal.
8214 Blair, Edw. J., Chicago, Ill.
8215 Ford, Leroy S., New York City.
8216 Rogers, F. T., Fon du Lac, Minn.

8217 Geib, Wm. V., Baltimore, Md.
8218 Louis, Henry C., Baltimore, Md.
8219 Raggio, V. E., Ft. Worth, Tex.
8220 Brown, Harry W., Boston, Mass.
8221 Simpson, J. A., Newark, N. J.
8222 Paddock, Orville W., N. Y. City.
8223 Maris, H. B., Ouray, Colo.
8224 Culverwell, J. A., Port Hope, Ont.
8225 Dunn, A. P., St. Paul, Minn.
8226 McWethy, W. E., Vallecito, Cal.
8227 Schley, Geo. B., Milwaukee, Wis.
8228 Wenger, J. A., Hamilton, Ont.
8229 Knopp, Otto A., Oakland, Cal.
8230 Orr, Samuel M., Jr., Abbeville, S.C.
8231 Serus, Elmer B., Wilkesbarre, Pa.
8232 Cooper, Albert, Brooklyn, N. Y.
8233 Craighead, J.R., Schenectady, N. Y.
8234 Scott, Ralph, Newark, N. J.
8235 Simon, Emil J., New York City.
8236 Brown, H. M., Niagara Falls, N. Y.
8237 Filkins, Barent L., Buffalo, N. Y.
8238 Cooper, Marion D., Madison, Wis.
8239 Payne, Harold G., Chicago, Ill.
8240 Collins, C. R., Wilkinsburg, Pa.
8241 Laughlin, H. H., Pittsburgh, Pa.
8242 Sanford, F. W., Ithaca, N. Y.
8243 Gibbs, Jesse B., Wilkinsburg, Pa.
8244 Jones, John P., Cedar Falls, Iowa.
8245 Plumb, Wm. H., Joliet, Ill.
8246 Pattberg, G. W., New York City.
8247 Anthony, Chas. C., Palo Alto, Cal.
8248 Lehman, Edw. L., Camden, N. J.
8249 Morse, A. L., Maynard, Mass.
8250 MacGuinness, Portchester, N. Y.
8251 Farrar, J. C., Empalme, Sonora, Mex.
8252 Wright, Chas. A., Cambridge, Mass.
8253 Walker, Glenn B., Wilkinsburg, Pa.
8254 Laird, Guy Morgan, Pittsburgh, Pa.
8255 Rhine, M., San Francisco, Cal.
8256 Talboys, Frank P., Wanganni, N. Z.
8257 Boyrer, Wm. C., Brooklyn, N. Y.
8258 Kennedy, W. C., Milwaukee, Wis.
8259 Rolph, Thos. W., New York City.
8260 Gawthrop, Ernst, Pittsburgh, Pa.
8261 Hall, Wm. H., Phila., Pa.
8262 Nesbitt, Robert N., Phila., Pa.
8263 Cooper, Orville, Fort Wayne, Ind.
8264 Hunter, Thos. B., Monterey, Cal.
8265 Atwater, Geo. F., New Haven, Conn.
8266 Cox, J. B., Schenectady, N. Y.
8267 Carter, E. B., Philadelphia, Pa.
8268 Chase, E. P., Wilkinsburg, Pa.
8269 Teffeau, Geo. W., Philadelphia, Pa
8270 Chynoweth, Geo., Ft. Smith, Ark.
8271 Boyd, Francis E., Brooklyn, N. Y.
8272 West, Judson Ray, Seattle, Wash.
8273 Menteth, W. F. S., Bombay, Ind.
8274 Mortensen, S. H., West Allis, Wis.
8275 Peck, Burt H., Chicago, Ill.
8276 Ridge, Samuel B., Pittsburgh, Pa.
8277 Steinbach, E. Sargent, N. Y. City.
8278 Fynn, Valere Alfred, St. Louis, Mo.
8279 Rhodes, Thomas B., New York City
8280 Sugg, Chas. R., Washington, D. C.
8281 Kirby, Omer, Chicago, Ill.
8282 Axtell, C. J., Schenectady, N. Y.
8283 Flagg, Lester L., Electra, Cal.
8284 Bragdon, W. B., Westbrook, Me.
8285 Ito, Ichiro, Tokio, Japan.
8286 Peaslee, A. S. L., Toronto, Ont.
8287 Chilson, J. H., Clifton, Ariz.
8288 Onken, Wm. H., Jr., Brooklyn, N.Y.
8289 Rochester, Thos. W., N. Y. City.
8290 Argabriti, N. M., Winona, Minn.
8291 Bernier, C. A., Winona, Minn.
8292 Bosch, Henry, San Francisco, Cal.
8293 Button, A. E., Schenectady, N. Y.
8294 Barroll, Lee, Cambridge, Mass.
8295 Boman, Carl E., Brooklyn, N. Y.
8296 Palecek, J. T., Schenectady, N. Y.
8297 Johnson, James C., Phila., Pa.
8298 Gay, Harold, Schenectady, N. Y.
Total, 117.

Applications for Transfer

Recommended for transfer by the Board of Examiners January 8, 1909. Any objection to these transfers should be filed at once with the secretary.

Henry Waterman Peck, Assistant Electrical Engineer, Rochester Railway & Light Company, Rochester, N. Y.

George Edwin Claflin, Electrical Engineer, United Electric Securities Company, 47 Ames Building, Boston, Mass.

Bradley T. McCormick, Chief Electrical Engineer, Allis-Chalmers, Bullock, Ltd., Montreal, P. Q.

Paul Spencer, Inspector of Electric Plants, United Gas Improvement Co., Philadelphia, Pa.

Robert Halsey Henderson, Manager of Works, Westinghouse Lamp Works Bloomfield, N. J.

Convention Papers, 1909

In accordance with Article VIII, Section 62 of the Constitution, the next annual convention of the Institute will be held elsewhere than in the city of New York, not later than the first of August 1909. The time and place of the 1909 convention has not yet been decided upon, but following a well established precedent it is likely that the convention will be held during the latter part of June or the first part of July. Both time and place will be announced later. The Meetings and Papers Committee has decided that fewer papers should be presented for discussion at this year's convention, so that more time will be available for discussion and social relaxation. At the 25th annual convention held at Atlantic City, N. J., June 29, to July 2, 1908, thirty-five papers, covering approximately 775 pages of the Institute PROCEEDINGS, were presented for discussion. It is probable that the number will be considerably reduced this year. As all of these papers must be printed in the PROCEEDINGS issued in advance of the convention, the Meetings and Papers Committee announces their convention plans now so that all members intending to present papers will have ample time in which to prepare their manuscripts. Before the plans for the convention can take definite shape it will be necessary to know the titles of all the papers to be presented, so that the various papers may be properly grouped and assigned for certain days. This is a work that requires time and thought, and as more papers are likely to be offered for presentation than can be properly taken care of, it is requested that prospective authors notify the chairman of the committee of the subject-matter of their papers not later than February 15, 1909. The manuscripts must be in the hands of the Chairman of the Meetings and Papers Committee before April 15, 1909.

The notices should be sent to Mr. A. H. Armstrong, General Electric Company, Schenectady, New York.

Annual Meeting A. S. M. E.

The annual meeting of The American Society of Mechanical Engineers was held in the Engineers' Building, December 1–4, with a membership attendance of 738. Six professional sessions were held at which papers upon related subjects were presented. Prominent features were the discussion of aerial navigation with a paper by Major Geo. O. Squier of the Signal Service, a symposium upon new developments in machine shop practice, a collection of papers giving the results of engineering test upon various materials and apparatus, a gas power session, and a steam and power plant session.

Two subjects along somewhat broader lines related to the relations of the engineer to the public, considering means by which he can best acquaint the public of the work which the profession is undertaking; and to the training of workmen, dealing with the conditions to be met by engineers who now have this duty to perform under modern systems of management.

On the evening of December 1 the retiring president, M. L. Holman, St. Louis, Mo., gave an address upon The Conservation Idea as Applied to The American Society of Mechanical Engineers in which many data and statistics upon the natural resources of the country and their use. Following this was the conferring of Honorary membership upon Dr. John A. Brashear of Allegheny, Pa., the astronomer and scientist and manufacturer of lenses and astronomical instruments. He responded with an entertaining illustrated lecture upon A Journey Among the Stars.

Another feature of the convention was a popular lecture on the evening of December 2 by Lieut. Frank P. Lahm of the Signal Service upon the Conquest of the Air in which he dealt with the accomplishments in the field of aeronautics in a most entertaining manner.

Simultaneous with the professional sessions were excursions to points of interest about the city in which the visiting members largely participated.

Some of the Early Work at New Britain, Conn., U. S. A.*

BY ELIHU THOMSON

It will be remembered that we started to build arc light dynamos in Philadelphia and ran the first machine at the bakery all night during the summer of 1879. The machine was run in a room which was sometimes during the summer at a temperature of 140 deg. fahr. by the thermometer, the machine being near the bake-ovens. The test was a severe one, but the machine did not burn out and is still in a working condition, after having been used for a long time after the bakery trial. There were some things about this machine which may as well be mentioned. It was, without doubt, the first three-phaser built. Its circuits were arranged so that it could be used with four separate circuits, or a series of four arc lamps at 20 amperes, or with 8 or 9 arc lamps with 10 amperes. To get the proper perspective it must, of course, be known that electric lighting in any form was a rarity in those days. It was this early work that caused the organization of the American Electric Company and the establishment of our business in New Britain, where, on March 29, 1880, we had 9 arc lamps in operation at the old basket shop, worked by a machine similar to the original just mentioned, with the addition of an automatic constant-current regulator, the first of its type. It may also be remembered that with this exhibit the current was carried to a separate building some distance away, and used to run a motor driving a circular saw for sawing wood. Like the dynamo, this was a three-phaser but with commutation, and the construction substantially survives in many of the small toy motors, it being one of the simplest possible. The old basket shop was an abandoned factory with a small engine and boiler, barely capable of keeping the lights going. I think that some of the wooden parts of the basket-making machinery fell a prey to the flames under the boiler when there was any chance of losing steam.

We began our work of constructing arc-light dynamos in New Britain in the fall of 1880, under great difficulties. They were so numerous that it would fill a fair catalogue to-day. The impossibility of getting wire without many joints, the limited machine equipment which forced us to design machinery which would not involve any planing, or as little as possible and then of only small surfaces, the lack of facilities for measurement, the unknown qualities of insulating materials, etc. As to measurement, it will probably be recalled that I brought a 10-ohm coil which I had made by comparison with a standard of Elliot & Brothers, London, the resistance box being among the apparatus of the Central High School. With this as a basis, and with the assistance of an improvised wheatstone bridge of a single stretch of wire, we made our coils of different values. We were compelled to limit ourselves to a tangent galvanometer which was known as the Western Union type, adapted more for telegraphy than for anything else; and for measurement of voltage of arcs we again had to improvise by a home-made astatic galvanometer and a resistance in circuit therewith, calibrated by a number of Daniell cells. This astatic galvanometer was used also with the bridge as a zero instrument.

The duties which fell to our lot in those early days were of the most diversified character. We had to be in part designing engineers and draftsmen, part business manager and patent attorney. I even remember cross-examining witnesses in patent interferences while in New Britain. Many of the early models of arc lamps, etc., were made at the lathe or bench by ourselves, and as the Patent Office in those days required models, there was oftentimes a struggle to get one prepared upon the filing of a case. It is interesting to note here that our pattern shop, which was in a different part of the building, was driven from the start by an electric motor which received current from the dynamo in the testing room, the field structure of which was adjusted to increase or decrease the torque of the motor, or its speed.

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* A letter read at a meeting of the Schenectady Section A. I. E. E., October 29, 1908.

It will be recalled to mind our discussing many things which later eventuated in the art, but our business being electric arc lighting and our facilities being limited, we had very little opportunity for turning aside into other promising channels of work. As a sort of diversion, we used occasionally to discuss them. Among these were the possibilities of the use of induction coils, now known as transformers, in distribution, and the possibilities of motive power transmission following on the equipment with one of our arc lighters with three rings instead of the commutator, or rather in addition to the commutator, whereby three-phase alternating currents could be taken; the possibilities of welding copper and other metals by electricity, using the reversed induction coil or step-down transformer, afterwards actually carried out in practice in Lynn in 1885. It may be interesting to mention that the original patents for our arc machine were filed with the idea of using the machine as a three-phase alternator with three rings, outside of its use with a commutator. It may be useful to mention that our chief prestige in the early days of electric lighting came from the employment of our automatic regulator for keeping the current constant in spite of the variations in the load, and that we were the first to equip arc lamps with shunting switches as a part of the structure, and advised that they be used freely to cut out lamps in the system. This was at a time when the stations in the cities had a large number of arc lamps hung up for filling in the load of dynamos which did not happen to be fully loaded outside; and, singular to relate, the practice was continued even while carbons cost as much as 6.25c. a foot, the positive carbons only lasting about 9 hours, and the negative about twice that. It was during the New Britain developments while increasing the capacity of our arc dynamos that we were led to the use of the air-blast, not, as has been frequently stated, to blow out the arcs at the commutator, but rather to prevent arcing by blowing upon the small terminal spark at the slots in the commutator and inserting a cold layer of air between the tip of the spark and the segment which was rapidly becoming of opposite polarity. The theory was much more refined than the mere blowing out of the sparks of arcs. As a mechanical problem it involved the construction of a small blowing apparatus which could withstand the high speeds of dynamo driving, in itself a matter of no little difficulty, but fortunately solved almost from the start. It was about this same time, 1882, that the early work in using magnetic blow-outs on lightning-arresters, switches, and commutators started. This development, of course, as the art advanced, became more and more important, especially in the railway work and lightning protection of railway circuits.

We had to satisfy the management in the early days that we could manufacture carbons for arc lights, and we made carbons experimentally in the old New Britain plant. I think we were able to construct, while there, dynamos of capacity of 30 arc lights in series. It was in these comparatively high-potential dynamos that built-up or pasted mica was first used for separating the coils. Its first form was a piece of paper upon which was laid a coating of shellac and then the split pieces of mica, another coating of shellac and more mica, crossing joints until the desired thickness was obtained, this method later being employed as the commutator method.

How difficult it was in those days to be sure of obtaining good quality and straight carbons! The regulating or derived circuit or shunt around the arc, you may bear in mind, had to be wound with wire which often varied not only in shape or section but in actual section from one end to the other of a hank or coil. As a consequence it was almost impossible to wind magnets of any definite resistance without selecting wire of varying diameter to make up an average. We could not buy fine wire which did not greatly vary, and the makers excused themselves on the ground that the wire could not be drawn without wear on the dies, which would change the gauge from one end to the other of a long coil of fine wire. I remember discussing this matter with one of the representatives of the principal firm making fine insulated wire in those days and suggesting that the wire should be drawn through a finishing die of diamond or sapphire. The company, soon after this, was advertising as its chief specialty, jewel-drawn wire invariable in gauge.

It may be interesting at this point simply to look back a little further in the art of insulating wire. My first acquaintance with the insulated-wire industry was in Philadelphia where, in 1875 or 1876, we had to go to a bonnet wire factory to get magnet wire. In those days, ladies' bonnet frames were constructed of steel wire coated with cotton braiding or cotton covering, and this was a large industry. The magnet wire being covered by similar machines, was a sort of addendum, as there was little call for it. There was, of course, a certain consumption of fine wire in the winding of telegraph relays and sounders, but very little of the larger size was called for and mostly for philosophical apparatus and a few plating dynamos. It is interesting to note that these bonnet wire factories, very soon after the advent of electric lighting as an industry, dropped the bonnet wire part and developed entirely into electric wire makers.

The New Britain days were certainly interesting, particularly after the Lynn management took hold and stimulated the work. Many of the devices which were developed there are still in use, use which has extended in various directions. They were in their incipient stage in the early work at New Britain. The film cut-out as an instance is one of them much used in series incandescent lamp work. I remember it, because I was personally called upon to become cross-examining attorney in an interference we had with two others on the same matter, one of whom was Mr. Wood, if I remember rightly, and the other Mr. Van DePoele, and we won our case.

Pioneer Work with the General Electric Company*

BY W. S. ANDREWS

I had the honor to be associated with Mr. Edison in the early days. Some of Mr. Rice's graphic accounts have brought back to me memories of the troubles and trials which we experienced in those old days for the lack of material and instruments; for instance, trying to measure volts without voltmeters, amperes without ampere-meters etc.

In the old days when we first started in with electrical wiring we had no wire of any kind, with the exception of a limited quantity of some that was single cotton covered. After a great deal of work, however, we persuaded some of the wire manufacturers to make for us what was called cotton-braided wire, which was covered with a coat of white lead, and known as Underwriters' wire. But this was far from perfect, as moisture took to it very quickly. After two or three fires happened, it was re-christened " undertakers' wire."

In 1883, on the fourth of July, Edison started his three-wire station in Sunbury, Pa. A quarter of a century ago; a short time to look back to, but a long time to look ahead to. In view of the fact that such tremendous strides have been made since that time, it may be interesting to give a short account of some instruments and apparatus which we used in Sunbury station, also in testing dynamos at that time.

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* A talk before the Schenectady Section A. I. E. E., October 29, 1908.

All dynamos of the Edison system were of the low-tension type, 115 volts being about the highest pressure used. These were all made at the Edison Machine Works, New York City. Three types of belt-driven machines were standard at that time. This was in 1882. These machines were standardized according to the number of 16-c.p. lights that they would carry without undue heating. There was the Z machine which would carry 60, the L which would carry 120, and the K, 240 —each size thus carrying double the number of lights of the one before it. These machines were shortly re-designed and re-lettered. The letters were picked out from the alphabet without regard to order at all. The largest was H, the next smaller, Y, then S, T, R, and G. Why these letters were chosen, I do not know. The men in the testing room, however, found it so difficult to remember them that they adopted the following sentence— the first letter in each word of which stood for a type letter of a machine.

" Have You Seen Thomson's Reflecting Galvanometer?"

In testing these machines electrically, they were connected to a large bank of lamps on the ceiling of the testing room which was very high. The bank consisted of about one thousand 16-c.p. lamps. There were no voltmeters at all, and the only means we had for measuring was by means of a standard battery made up of very small Daniel cells. The solution was carefully made of chemically pure acid and distilled water. It was supposed that the electromotive force of these cells was 1.079. We connected them in series with a Thomson galvanometer and high resistance of 20,000 or 30,000 ohms; a very crude way, but the best we had. It was my especial duty, once each week, carefully to clean the battery and renew the solution so as to insure the voltage remaining constant.

It was also common practice to check the candle power of incandescent lights by comparing them with a standard candle which was supposed to burn 120 grains of tallow in an hour. Of course we had to weight this before and after burning.

As early as the '80's, as Mr. Rice has already said, the term " weber " was used. This was afterwards changed to " ampere " in '85, at least in the Edison Machine Works. Later on, the electrical unit of power became popularized by the name of volt-ampere, afterwards changed to watt. Edison's dynamos were rated in 16-c.p. lamps as late as 1890. At this time it became general to rate them in watts or kilowatts. It was thought by some a great mistake to rate dynamos in kilowatts at that time.

In regard to measuring amperes, the method we adopted down there was to take strips of German silver, and, knowing the volts and resistance, we could figure out amperes. In order to measure amperes from " jumbo " dynamos, which delivered 400 or 500 amperes, we used so-called shunt boxes— these being about 4-ft. long and 24-in. square. We generally calibrated the galvanometer as we naturally would, so as to read in amperes direct without any calculation. In regard to the measurement of electrical resistance, I do not know that there is any method in use at the present time which is better than the one we had then.

The only means of maintaining normal voltage in lighting plants was by observing a pilot lamp located on the headboard of the dynamo. When a man was sent out to set up a dynamo he would show the engineer how bright this pilot lamp ought to burn at the proper voltage.

In large isolated plants, Edison automatic regulators were sometimes used; but these devices did more harm than good because they relieved the operator of responsibility. Edison would not have them because he paid men to regulate the voltage, and insisted that this was part of their duty. Automatic regulation also was expensive, and I know cases where the regulator cost more than the dynamo.

The story of the Cumberland station is worth recalling here. Word came to Edison in New York that the Cumberland people were burning out armatures rapidly. I made my appearance at the station in the evening and was met by a colored man, the engineer. I asked him if he were the only attendant, and if he attended the boilers, engines, machines, etc. He said " Yes, sah; I'm a hustler!" I asked him if he had been burning out armatures lately, and told him that I had come from New York to give him advice. I then asked him how he knew when the dynamos were carrying too much current. He said that some one had told him that when the wires were carrying too much electricity they would get hot. He therefore felt of the wires occasionally, and if he found one getting hotter than the others, he would put in a little more resistance and cool it down. As far as I know, this is the first record we have of a " hot wire " ammeter.

I went back and reported to Edison. Edison said, " We have got to get up an ammeter." We set to work and made some in about a week or so. We got up the old Edison pendulum ammeter, and the first sample of this device was shown to Edison at the machine works. He said it was pretty good, but that we needed something rough. " Have six made up. When you examine and test them in the testing room, have them packed and then call me. I do not care to see them until packed and ready for shipment." When this was done, he was notified and came in. Edison said, " Put them on the table. Now, then, get up on the table and kick em' off; for if they won't stand this, they will never reach Cumberland in operating condition." They were kicked off the table as hard as the fellow could kick them, and sent spinning over the floor. Edison then said: " Now I will look at them." Then after a careful examination, they were approved for shipment. It is needless to say there were no jewel bearings in the instruments at that time.

Sections and Branches

BALTIMORE SECTION

The December meeting of the Baltimore Section was postponed in order that the members of the Section could hold a joint meeting with the engineering section of the American Association for the Advancement of Science in its Sixtieth Convention, which was held in Baltimore. An invitation was extended to the members of the Washington Section to take part in the meeting, some of whom attended. The joint meeting took place on December 30, 1908. The evening was devoted to a paper by Dr. J. B. Whitehead, entitled " The Electrical Operation of Steam Railroads."

BOSTON SECTION

The regular meeting of the Boston Section was held at the Edison Building on Dec. 16, with Dr. A. E. Kennelly in the chair. The speaker of the evening was Mr. A. Stein, of the National Electric Signaling Company, Brant Rock, Mass. Mr. Stein described the apparatus used in wireless telephony, pointing out that the best results in producing current without sound have been obtained with a high-frequency alternator of the inductor type, having for its rotating part two steel disks about 12 in. in diameter, slotted, and speeded up to revolve 16,000 turns per minute, giving a frequency of about 80,000 cycles per second. There is an 80 mil air gap. There are 600 slots with 300 armature coils. These armature leads are connected to the antennas and ground, and by tuning with the inductance a resonant voltage is built up on the antennas to approximately 25,000 volts. Another type of high-frequency alternator under development has a single disk with two armatures facing it, and the result is a better efficiency; probably around 60 per cent.

For transmitting, the condenser type and the carbon type have both been tried. The condenser transmitter is simply two plates that are separated by mica. The back plate is a metal sheet, and the front plate, which is directly connected to the diaphragm of the transmitter, is a gold-covered mica plate. In case the antennas are radiating energy, the condenser transmitter is shunted directly across the inductance. In talking into the transmitter the plates vary the distance and hence the amount of leakage that goes down the path produced by the condenser transmitter. The ordinary Bell type of transmitter was tried, but it heated so much that after three minutes' use the talking would decrease perhaps 90 per cent. In a special form two metal plates were water-cooled. Between them is a soapstone ring filled half way up with carbon. A piece of platinum is set centrally in this space between the rings, dipping into the carbon and connected to the transmitter so as to move with the talking. Other modifications have been made, and it is now easy to carry 10 amperes or 15 amperes on a transmitter without trouble. The receiver used is of the liquid type, similar to that used in wireless telegraphy. The variations in the receiver follow closely the variations in the resistance of the acid as the waves enter it. The talking is clearer than talking on an ordinary land line. Simultaneous talking and receiving have been made possible by the use of an artificial antenna circuit. It has a capacity which is balanced against the capacity of the regular antennas, and an inductance, which is also balanced in a similar manner. The other station gets the signals because the amount of current flowing in the antenna circuit is varied by the transmitter. When the other station starts to send, the antennas themselves are affected, and the artificial is not affected, so that half the current goes through the artificial antennas.

With the high-frequency alternator method, reducing the waves for telephonic purposes, the Brant Rock station has talked with Jamaica, N. Y., 200 miles away. The tower has eight 300-ft. cages spread out in umbrella shape, with a radiation resistance of about 8 ohms. The energy radiated by the antennas in sending 200 miles was something over 700 watts. The current in the antennas was from 7.5 to 8 amperes. The total amount of energy expended, including the rather inefficient type of alternator used then, was about 7 h.p. The system is slightly more selective than the wireless telegraph in that in using the machine one has a very peaked wave. The tuning is very short on account of the pure sine wave, although its secrecy is not absolute. The only way that it could be changed would be by varying the speed at times. The quality of speech does not vary any for the distance except in loudness.

CHICAGO SECTION

Between 400 and 500 engineers and others interested in light and illumination attended the opening meeting of the Chicago Section on the evening of December 17, 1908, to hear the address of Dr. Charles P. Steinmetz on that subject. Just before the meeting the local committee of the Section entertained Dr. Steinmetz at dinner, at the Engineer's Club. There were also present at the dinner, Mr. Louis A. Ferguson president of the Institute, Mr. Bion J. Arnold, past-president of the Institute, Messrs. Johnson and Lyman, Professor Morgan Brooks, of the University of Illinois, and Messrs. Abbott, King, Woodmansee, Woodworth and Wray, of the local committee. This meeting, as well as the Steinmetz meeting of a year ago, proved so successful that it has been suggested that the Steinmetz meetings be made annual affairs.

CLEVELAND SECTION

A meeting of the Cleveland Section was held on December 21, 1908, at the Case School of Applied Science, 53 members and visitors being present. Professor H. B. Dates was the principal speaker, selecting as his subject "The Olbrecht Photometer and Arc Lamp Photometry." He spoke on the design and use of the Olbrecht Sphere, which was illustrated by a .5 and a 2-meter sphere. He was followed by Dr. Springsteen, who made a mathematical demonstration of the theory of the sphere. Dr. Hyde spoke on the Matthew photometer and the effects of frosting of incandescent lamps. Dr. Ladolf pointed out the advantages of the sphere in arc light photometry. Mr. Cady discussed its use with Nernst lamps. Many other members contributed to the discussion.

FORT WAYNE SECTION

The Fort Wayne Section held its regular monthly meeting on December 16, 1908, at the Anthony Wayne Club. The meeting was preceded by an informal dinner in honor of a number of out of town guests. Many of the members of the Section and a large number of guests attended the dinner, and there was a still larger attendance at the meeting. In a brief after dinner speech, Judge R. S. Taylor spoke of the pioneer development in electric lighting, with special reference to that in Fort Wayne. At the close of Judge Taylor's remarks the meeting was called to order, and Mr. E. A. Barnes, superintendent of the Fort Wayne Electric Works was introduced as the speaker of the evening. Mr. Barnes subject was "Choice of Power for Manufacturing Industries." He dealt with the various phases of power which can be used for manufacturing industries, taking up successfully power purchased from central stations, power from gas and fuel-oil engines, gas producer engines, and power furnished by hydroelectric development. Finally, Mr. Barnes took up the relative merits of reciprocating and turbine engines, dwelling at some length on this question, and considering the relative merits of both the condensing and non-condensing types. He pointed out advantages which he claimed for the reciprocating and turbine non-condensing engines in northern latitudes, where for eight months in the year it is necessary to supply heat to factory buildings, thus utilizing the exhaust steam from the non-condensing engines. He had figures to show that the value of the heat from exhaust steam would make a saving which would more than counter-balance the saving in coal consumption which would be gained by using condensing engines. The following gentlemen took part in the discussion of the paper: E. B. Raymond, I. F. Baker, John Riddell, J. E. Franzen, C. W. Sponsel, R. S. McNeil, J. J. Kline; and E. A. Wagner.

IOWA STATE COLLEGE BRANCH

The first meeting of this Branch was held September 16, 1908. It was devoted exclusively to experiences during the summer. The following papers were presented: "Inspecting for the Commonwealth Company of Chicago", by Mr. Elyea; "House Wiring", by Mr. Humphrey; "Telephone Work", by Mr. H. C. Smith; "Construction of a Special Engine", by Mr. Bek; "On Automobiles", by Mr. George Mills; "Conduit and Panel Wiring at the Union Pacific Railroad Shops", by Mr. H. N. Kolb; "Steam Piping", by Mr. Floyd Breeden; "College Wiring—Motor Experiences", by Mr. Joe King. A resolution was adopted to insert a card in the college paper announcing the dates of Branch meetings during the current year. Forty-six members were present at this meeting.

October 7, 1909. Professor Fish presided at this meeting, with 51 present. Professor L. B. Spinney presented a paper on "A New Primary Standard of Light", explaining Dr. Steinmetz' proposal lately published in the Institute Proceedings. Professor Spinney emphasized the fact that light is more of a physiological quantity that physical, and hence the difficulty of securing a reliable and reproducible standard. He then proceeded to give the historical development of standards of light, explaining the various methods of measurement proposed and followed, concluding with Dr. Steinmetz' proposal in his Institute paper " Primary Standard of Light ", published in the November 1908 Proceedings.

Mr. F. D. Paine then gave a paper on " Present Tungsten Lamp Situation ", showing the development of the incandescent lamp and the remarkably rapid improvement made in the Tungstens. The paper was illustrated by the several types of incandescent lamps connected up for the purpose.

A short business meeting followed in which it was decided to arrange for a banquet on October 28.

October 11, 1908. A special meeting was called to consider the nature of the social meeting for October 28. Twenty-three members responded to the call. Mr. Bek presented the report of the social committee. A motion made to extend invitations to the ladies was lost, after which it was decided to limit the attendance at the social gathering to Branch and Institute members only. It was voted to hold the banquet in honor of Mr. H. A. McCune, who was soon to leave for the east. Arrangements were then made to push the affair to a successful conclusion. It was voted to hold the next regular meeting of the Branch on October 20 instead of the 21st, as the latter is set aside by the college as College Day.

October 20, 1908. The executive committee decided to call off this meeting, learning beforehand that the attendance would be slim.

October 28, 1908. This evening was devoted to a banquet given in honor of Mr. H. A. McCune, soon to leave the college. Forty-eight plates were laid, beside which were as many electrically and magnetically worded menu cards. The toasts offered were many and varied, largely worded in technical figures of speech. The only feature to mar the pleasures of the evening was the feeling of regret that Mr. McCune was to sever his connection with the college and the Branch. The event proved a great success.

November 18, 1908. Thirty members and one visitor attended this meeting, at which Mr. Bek abstracted Messrs. Junkersfeld and Schweitzer's Institute paper on " High Potential Underground Transmission ". Messrs. Fish, Crouse, Schuff, Hanssen, Bek, Kirkpatrick, and Warsaw took part in the discussion. At the business meeting Mr. H. W. Wagner's resignation from the executive committee was presented and accepted. Mr. Humphrey was elected to succeed Mr. Wagner. A committee was appointed to arrange for an electrical show to be held in April and to be carried to a conclusion entirely by the Branch. Mr. Frank K. Shuff was elected chairman of the committee.

University of Kansas Branch

This Branch held a meeting on December 17, 1908, at which Mr. Ray Jones presided. Mr. George Ahlborn gave a talk on " The Installation and Operation of the Electric Power Plant of a Cement Plant." Some discussion followed Mr. Ahlborn's talk.

Twenty-nine members and visitors attended the meeting of the University of Kansas Branch on January 7, 1909, with Mr. V. S. Foster in the chair. Mr. Frank Phillips, a graduate of the university, class of '07, gave a talk on " The Testing Department of the General Electric Company." Mr. Phillips has been in the employ of the General Electric since his graduation. Following the talk he was asked various questions relating to the work by some of the members present.

LEHIGH UNIVERSITY BRANCH

The third regular meeting of this Branch was held on December 15, 1908, with 60 members present. Mr. A. S. Garrison presided. A resolution was offered and adopted that the local secretary send notices of meetings of the Branch to all members of the Institute residing in the vicinity of the university, with a view to having larger attendances. Professor Esty then explained the requirements for Student enrolment in the Institute, pointing out the advantages offered to enrolled Students. Professor Esty was followed by Mr. J. L. Hays, with a paper on "Car Lighting Equipment." Mr. Hays first dealt with the early developments, concluding with a classification of the various systems now in operation. The second paper, by Mr. C. A. Hoppock, on "Grounding of Neutral in Polyphase Systems", was an able discussion of its advantages and disadvantages. The final paper, on "Car Lighting Equipment", was presented by Mr. Cartwright, of the Lehigh Valley Railroad. Mr. Cartwright spoke of the early and more modern systems of car lighting, and gave many interesting points drawn from his wide experience. After the discussion following the paper the meeting was adjourned, and refreshments were served.

MEXICO SECTION

The Mexico Section held a meeting at the American Club, Mexico City, on December 2, 1908. Mr. R. F. Hayward was the presiding officer, and there was an attendance of 27. After an informal dinner the Institute paper on "High Potential Underground Transmission", by Messrs. Junkersfeld and Schweitzer, published in the October 1908 issue of the PROCEEDINGS, was discussed by those present.

UNIVERSITY OF MICHIGAN

November 4, 1908. About 30 members and visitors were present at this meeting. Mr. R. D. Parker gave an interesting lecture on automatic telephone systems. After the discussion Mr. Parker invited those present to the apparatus room of the university and demonstrated the working of the automatic apparatus from subscriber to subscriber.

December 2, 1908. The nominating committee presented its report to this meeting, and the following officers were elected for the ensuing year: P. R. Moffett, secretary and treasurer; W. A. Burnham, recording secretary; H. C. Roys, librarian; C. W. Hall, chairman and vice-chairman, program committee. A. G. Hall, chairman, membership committee. An executive committee was appointed, to consist of Professor G. W. Patterson and the above named officers. The program for the coming year was discussed, after which the meeting was adjourned.

December 16, 1908. Electric heating was the topic discussed at this meeting. Chairman Baxter read extracts upon the subject from past numbers of the Institute PROCEEDINGS and from several technical journals.

UNIVERSITY OF NEBRASKA

December 1, 1908. Mr. V. L. Hollister presided at this meeting, with a total attendance of 17. Mr. Clarence Johnson described a change of belt drive to three-phase motor drive in the Evans Laundry Company's plant in Lincoln, bringing out many practical points. Mr. I. F. Baker discussed the Institute papers on the electrification of steam roads, by A. H. Armstrong, printed in the October 1907 PROCEEDINGS, and L. B. Stillwell and H. St. Clair Putnam, January 1907 PROCEEDINGS.

PHILADELPHIA SECTION

The Philadelphia Section held its regular monthly meeting in the Philadelphia Electric Company's building on January 11, 1909. Mr. Paul Spencer presided, and there was a large attendance. Mr. J. B. Klumpp presented a paper on "The Use and Operation of Gas Engines in Central Station Work." The following gentlemen took part in the discussion on the paper: Messrs. Heywood, Klumpp, Painter, Eglin, Spencer, McLeod, Keith, Weeks, Rice, Goodwin.

Pittsfield Section

A large number of members and guests of the Pittsfield Section gathered at the Wendell Hotel on December 23, 1908, to hear the address of Mr. Charles B. Burleigh, of Boston, on "The Steam Turbine." It was illustrated throughout with numerous lantern slides. A review was given of the historical side of the subject, and was followed by an explanation of the principles upon which the several types of turbines are based, together with a description of their construction and operation. The speaker then called attention to the numerous applications of the steam turbine from the driving of a one-half horsepower dynamo furnishing current for the electric headlight of a locomotive to its use in some of the large power stations where sizes capable of delivering thousands of kilowatts of electrical energy are in daily operation. This was followed by a graphic description of some of the latter equipments of turbine-driven ocean liners and several of the battleships and cruisers now in course of construction or in actual operation, which are provided with powerful prime-movers of this general type. After the lecture Mr. Burleigh exhibited a number of actual working parts taken from steam turbines of various sizes and designs.

Mr. T. C. Martin, past-president of the Institute, and editor of the *Electrical World*, was the guest of honor at the meeting of the Pittsfield Section held January 8, 1909. Prior to the meeting a dinner was served in the private dining room of the Wendell Hotel. One of the pleasing little surprises of the evening was the use of electric coffee percolators, cracker toasters, and cigar lighters. Those present at the dinner were: T. C. Martin, C. C. Chesney, Stephen D. Field, Frank R. Whittlesey, Joseph Insull, S. H. Blake, John M. Gilmore, E. F. Gehrkens, W. J. Woolridge, S. E. Johannesen, H. W. Tobey, Carl Groat, C. S. Hayward. Immediately after the dinner the party repaired to the large dining room of the hotel, where Mr. Martin delivered his address on "Engineering Aspects of our New Public Service Commissions." Mr. Martin made a careful review of public service commissions from the engineers' standpoint.

Purdue University Branch

November 17, 1908. This meeting was held in the electrical building of the university, vice-chairman J. R. Ong presiding. Mr. E. C. George introduced the subject of electric heating. He outlined the principal advantages and disadvantages in the use of electricity for heating. At the present time the use of electricity for heating is limited mainly to small devices, such as irons, chafing dishes, soldering irons, etc., unless electrical energy can be had at an exceptionally low price, as is sometimes the case near hydroelectric plants. Station managers find it much to their advantage to promote the use of heating apparatus, in order to build up their non-peak load. Mr. George also described a system of electric residence heating now in practical operation. The chief point of interest in this installation is that the heating system is primarily a hot water system, but different from the ordinary in that the boiler is heated by electrical energy.

Instead of the regular meeting on the evening of December 1, 1908, the members of the Branch inspected the newly installed system of street lighting at the Merchants' Electric Lighting plant of Lafayette. This portion of the plant, the magnetite arc system of lighting, was put into operation about September 1, 1908. The system is unique in that the transformation from alternating current of high voltage to direct current of constant value is based on the action of a mercury arc converter. The system is divided into seven circuits of 45 lights each, or a total of about 315 lights. Each circuit has its own transforming unit, which consists of a constant current transformer and a mercury arc rectifier. There is a small single-panel switchboard for each transformer unit. At the top of each switchboard is placed a signal lamp which is connected in the lighting circuit, roughly indicating the condition of the circuit. The arc rectifiers seldom break or burn out, but when they do, can be replaced in a few minutes. The arc lamps used in this system were points of particular interest. Instead of carbon, the lower pole is of copper, which seldom has to be replaced, while the upper pole consists of magnetite which is held in the form of a stick by a tin covering. This upper pole burns about every 300 hours. The lamp burns with a steady clear light making little or no noise. The lamps were not in service on the night of the inspection, but were turned on for a few minutes to show the working of the transformers.

December 6, 1908. The Branch was addressed on this evening by Mr. A. B. Cole, on the subject "Some Phases of Maintenance of an Electric Railway." The speaker having been employed for a considerable length of time by the Grand Rapids, Grand Haven and Muskegon Railway Company, was well qualified to talk on the subject chosen. About 40 lantern slides served to illustrate the many points in the lecture. The Grand Rapids, Grand Haven and Muskegon Railway is a third-rail system, operating 17 passenger cars, nine express cars, and one construction car. The company's shops are the best equipped in western Michigan. The main shop, machine shop, paint shop, storeroom, armature room and master mechanic's office are combined with the car barns in a modern steel and brick building. There are in the building a total of seven tracks, three of which are in the main shop. One of these tracks is a pit track capable of pitting two cars at a time. The main shop is served with two ten-ton cranes With these shops the company is enabled to do all of its own repair and construction work. Mr. Cole exhibited a series of views showing different parts of repair work in progress. Another series of views showed the different types of cars and equipment used. There were two types of third-rail shoes shown; one a long inverted trough-shaped shoe for track covered with sleet, and a short flat shoe for track under ordinary conditions. The passenger cars are equipped with two 150 h.p. motors capable of a maximum speed of 60 miles per hour on a schedule that requires an average speed of 43 miles per hour. The express cars are equipped with two 75 h.p. motors capable of a speed of 35 miles per hour. An interesting fact was brought out in regard to the method of making third-rail crossings at railways. The latest method employed is to connect the two sections of third-rail, terminating at each side of the railway, by a cable carried overhead, instead of underground as was formerly done. This is on account of the electrolytic action which occurs where the underground cables connect to the third rail. The sub-stations are each equipped with a structural steel horse on which are mounted traveling hoists for handling sub-station machinery when repairs are needed. Another particularly interesting fact which Mr. Cole brought out is that the company uses an additional power rail for about eight miles, as a direct-current feeder. Ordinarily the sub-stations are placed about every 10 miles with no direct-current feeders between except the third rail.

ST. LOUIS SECTION

At the December meeting of the St. Louis Section, held on the 9th instant, 30 members and guests were present, with Mr. O. Wiemer presiding. The evening was devoted to a paper read by Mr. Wiemer, on "Water Power Development in the West." Mr. Wiemer spoke from personal observations made by him on a recent tour of inspection of various high-tension plants along the Pacific coast. Numerous lantern slides were shown of the different plants.

SAN FRANCISCO SECTION

There was a large attendance at the meeting of the San Francisco Section held November 27, 1908, over a hundred being present. Officers for the ensuing year were announced as follows: C. W. Burkett, chairman; S. J. Lisberger, secretary. Mr. C. W. Bartholomew, western manager of the Westinghouse Air Brake Company, read a paper on "Air Brakes for Freight and Passenger Trains."

SCHENECTADY SECTION

December 10, 1908. At this meeting Professor E. E. F. Creighton presented a paper on "The Recent Study of Lightning Phenomena on Colorado Transmission System." The lecture was profusely illustrated by lantern slides.

December 17, 1908. Mr. H. W. Tobey, of Pittsfield, presented a paper on "Recent Developments in Transforming Apparatus." The first part of the paper was descriptive of developments in transforming apparatus. The second section was described by means of lantern slides.

Both meetings were as usual largely attended.

SEATTLE SECTION

The regular December meeting of this Section was held in the rooms of the Chamber of Commerce December 19, 1908. The offer of the "Journal of Electricity, Power and Gas", of San Francisco, to publish papers and discussions of the Section was read and accepted, authorization having first been obtained from Institute headquarters. The letter of Mr. D. B. Rushmore, chairman of the Institute committee on industrial power, requesting that one meeting be set apart for consideration of some phase of industrial power was referred to the executive committee with power to act. Mr. Magnus T. Crawford, of the Seattle-Tacoma Power Company, introduced the subject of the evening, entitled "Notes on Transmission Practice in the Northwest." Mr. Crawford presented an interesting résumé of transmission conditions as worked out in the region tributary to Puget Sound. He described in detail, and illustrated with drawings, the transmission systems of the Puget Sound Power Company, the Seattle-Tacoma Power Company, the Seattle Municipal Power Plant, and the Whatcom County Railway & Light Company. Of these four companies three transmit at approximately 30,000 volts, and one at 55,000 volts. The distance between conductors, on these systems, all of which are to be raised to 55,000 or 60,000 in the near future, ranges from six to seven feet. The insulators used are tested for approximately double the line voltage. Wooden pins have in most cases been replaced by wrought iron pins, with a resulting lower leakage loss. Aluminum has been found very satisfactory by the two companies using it, notwithstanding the difficulty of making joints as compared with copper. Following the paper, Chairman Harisberger introduced Mr. Ralph D. Mershon, of New York City. Mr. Mershon was cordially welcomed by the Section, and responded with some valuable data on transmission problems. The paper was discussed by the following gentlemen: Messrs. Harisberger, Hawes, Whipple, Hoskins, Magnusson, Moore. A number of others present took an active part.

SYRACUSE UNIVERSITY BRANCH

A meeting was held December 17, 1908, at which Mr. W. L. Campbell's Institute paper, "A Study of Multi-office Automatic Switchboard Telephone Systems", was presented by

Mr. George Wagschal. This was followed by a general discussion of automatic telephone systems.

TOLEDO SECTION

The meeting of January 4, 1909, was devoted exclusively to business. Officers were elected from the executive committee as follows: C. R. McKay, chairman; M. W. Hansen, vice-chairman and chairman of program committee; George E. Kirk, secretary; Jos. W. Sharp, chairman of membership committee; W. A. Hill, treasurer. Chairman McKay outlined the subjects for efforts are being made to procure speakers for the current year. He then discussed in a general way the desirability of closer relations being fostered between individuals and their organizations interested in technical work in the vicinity.

TORONTO SECTION

At its regular monthly meeting, December 18, 1908, the Toronto Section had as its guest, Mr. Henry G. Stott, past-president of the Institute, and superintendent of motive power, Interborough Rapid Transit Company, New York City. During the afternoon Mr. Stott, in company with Mr. R. G. Black, electrical engineer of the Toronto Electric Light Company, and Mr. W. B. Boyd, chief engineer of the Toronto Railway Company, visited the terminal station of the Electrical Development Company, of Toronto, and the various distributing stations of the railway and lighting companies. Previously to the meeting 37 members of the Section enjoyed an informal luncheon at the St. Charles Café, with Mr. Stott as their guest. The meeting was the most interesting and successful in the history of the Section. There were present 80 members of the Section, and 34 visitors from other local engineering societies. Mr. Stott presented the paper for the evening, entitled " Notes on Cost of Power ", in which he dealt very fully with the subject. Complete curves were presented showing the relation between load-factor and fixed charges for different plant costs; the cost of power per kilowatt-hour and per kilowatt rated capacity at all percentages of rated load for reciprocating steam plant, steam turbine plant, reciprocating and low-pressure steam plant, gas-engine plant, gas-engine and steam-turbine plant, and hydraulic-turbine plant. Typical summer and winter railway load-curves were then shown, together with typical winter and summer lighting load-curves and typical industrial curves, which were followed by a series of curves showing the variation in the total cost of power during the day for each of the several plants previously discussed, when operating with the various typical load-curves. The total cost of power and the operating cost of power for the various plants was also graphically shown. The subject matter of the paper proper, in connection with these curves, proved very interesting and resulted in an extended discussion. Among those who took part in the discussion were: Messrs. W. N. Ryerson, Dean Galbraith, Thomas R. Roseburgh, C. H. Mitchell, P. W. Sothman, K. L. Aitken, R. G. Black; Wm. C. Angus, W. A. Bucke, Edward Richards, A. L. Mudge, H. W. Price, H. F. S. Strickland, H. E. M. Kensit, and W. A. Hare.

URBANA SECTION

The Urbana Section held its regular monthly meeting on December 16, 1908, in the electrical engineering laboratory of the University of Illinois. Professor Ellery B. Paine presided, with a total attendance of 49 members and visitors. Mr. D. C. Faber abstracted the paper read before the Institute by Mr. W. S. Murray, entitled " The Log of the New Haven Electrification ", which aroused considerable interest. A somewhat lengthy discussion followed. Mr. J. M. Bryant commented on the design of the generators; Mr. Amrine on the telephone interference; Professor Morgan Brooks on the interference and circuit breakers. Mr. Wenger spoke of the difficulties which are certain to arise in new enterprises and of the criticism which naturally follows any delays in the operation of railway trains. He also commented on the daring of the engineers, and of the information to be obtained from the operation of such a system, located as it is in close proximity to another great railway operated on a different system.

WASHINGTON SECTION

The Washington Section had a joint meeting with the Washington Society of Engineers, at Hubbard Memorial Hall, Washington, on November 24, 1908. Mr. P. A. Davis, president of the society, presided, and the total attendance numbered 100. The meeting opened with the executive business of the Washington Society of Engineers. Following this, papers were read on the subject of "Conservation of Natural Resources", by Mr. John H. Finney, Secretary Appalachian Forest Association, Mr. F. G. Plummer, U. S. Forest Service, and Mr. R. H. Bolster, U. S. Geological Survey. The papers were illustrated by lantern slides.

On December 30th, 1908, the members of the Section met with the Baltimore Section at a joint meeting with the American Association for the Advancement of Science. Dr. John B. Whitehead, chairman of the Baltimore Section presided at the meeting. Owing to the inclemency of the weather, not many of the members from the Washington Section were able to be present.

UNIVERSITY OF WISCONSIN BRANCH

The regular monthly meeting took place on December 16, 1908, in the auditorium of the Madison City Library. About 50 members, students and visitors were present. Mr. C. I. Zimmerman presented a paper on "Present Power Development at Niagara Falls." Having spent three or four years in the Niagara district and given especial attention to the power developments, Mr. Zimmerman was thoroughly familiar with the subject, and gave a very interesting address, dealing with the geologic formation, the power available, and its development up to the present time and the uses to which it is applied. Mr. M. D. Cooper read a paper on "A Method of Determining the Cost of Electrical Energy." This was an effort to analyze the factors which go to make up the cost of energy in a steam electric plant and introduce them into an equation for the determination of the cost of power in a given plant. The discussion on this paper seemed to indicate that the general feeling was that while such a study is interesting there are so many widely varying conditions to be considered that such equation would be of little use when applied to a specific case.

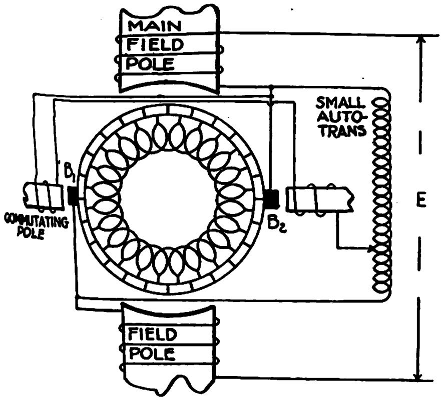
WASHINGTON STATE COLLEGE BRANCH

This Branch held a meeting on December 15, 1908. There was a total attendance of 24. The business session was devoted to the college annual. It was voted to have a photograph of the members of the Branch in the annual, and a committee was appointed to arrange the details. The business disposed of, Professor H. V. Carpenter read Mr. W. S. Murray's Institute paper on "The Log of the New Haven Electrification". Mr. M. K. Akers contributed to the discussion of the paper.

WORCESTER POLYTECHNIC INSTITUTE BRANCH

In a paper presented before the Branch on January 8, 1909, under the title "Commutation in Alternating-Current Series Motors", Dr. A. S. McAllister, associate editor of the *Electrical World*, outlined the difficulties relating to commutation encountered in alternating-current series motors.

These difficulties are not attributable to the alternation in the armature current but are caused by the rate of change in the field flux. There is produced in the armature coil under the brush by transformer action an active electromotive force which in a large 25-cycle motor would usually reach a value of from 6 to 20 volts. It is the rupture of the current produced by this e.m.f. that causes the vicious sparking in the plain alternating-current series motor. Although no simple methods have been devised for eliminating this e.m.f. under starting conditions, many effective schemes are now employed to neutralize it under running conditions, and the resistance-lead method of minimizing the current produced by this e.m.f. under both starting and running conditions has proved absolutely satisfactory. The best arrangement for eliminating the transformer e.m.f. under the brush is one involving a construction similar in all important details to that of the direct-current interpole motor. However, the method of obtaining the desired result differs in one important detail; instead of connecting the coils on the interpoles in series in the armature circuit, they are joined in parallel with the armature in such a way as to allow the e.m.f. impressed upon these coils to be decreased as the speed is increased.



A convenient arrangement by means of which the cause for sparking can be entirely eliminated under speed conditions is indicated in the accompanying diagram.

The flux in the commutating poles is in time quadrature to the main field flux, and hence the speed-generated e.m.f. in the coil under the brush is in time-phase (opposition) with the e.m.f. generated in the same coil by transformer action of the field flux. The e.m.f. on the commutating pole coils should be made to vary directly with the value of the main field flux and inversely with the speed of rotation; this condition can readily be obtained by means of the auto transformer. For the purpose of improving the power-factor it is desirable to place on the field core a compensating coil conductively associated with the armature; this feature is not essential to perfect commutation, and is not shown in the illustration. By connecting resistance in parallel in the main field winding the power factor may be increased to unity, or the motor may be cause to draw leading (condenser) wattless current from the system.

New Sections and Branches

A new Section has been organized at Madison, Wisconsin. This Section was formerly the University of Wisconsin Branch, but the increasing attendance at its meetings and additions to the local membership made it desirable for the Branch to develop into a Section. Accordingly a petition for authority to make this change was signed by 25 Members and Associates of the Institute, located at Madison and vicinity. This petition was considered by the Board of Directors at the meeting held January 8, 1909, and the desired authority was granted.

That interest in local development continues, is manifested by the number of requests recently received at the secretary's office for information as to the method of procedure and requirements for the establishment of Sections and Branches. Among these was a request to the Board of Directors for authority to establish a Branch at the Case School of Applied Science, Cleveland, Ohio. The desired authority was granted at the meeting of the Board held January 8, 1909.

Personals

Mr. F. P. Catchings, electrical engineer for the Georgia Electric Company, has been transferred from the Gainsville, Ga. to the Atlanta, Ga. office of that company.

Mr. C. L. Knopf has severed his connection with the Ohio State University and is now instructor of machine shop practice at the Oregon Agricultural College, Corvallis, Oregon.

Mr. Howard S. Denham, cable tester for the New England Telephone and Telegraph Company at Boston, has been assigned to the Central Division of the company, with headquarters at Lowell, Mass.

Mr. J. G. Jackson, formerly with the New York Edison Company, has recently been appointed assistant engineer by the city of Toronto, in connection with the new Niagara power distribution system.

Mr. Hugh G. Stokes has left the firm of Hall Bros., engineers, of Atlanta, Georgia, and is now connected with the Tennessee Coal, Iron & Railway Company, in the land department, on water supply investigation.

Mr. Carl F. Lambert has resigned from the engineering department of the Westinghouse Electric & Manufacturing Company, and is now connected with the W. K. Palmer Company, engineers, of Kansas City, Mo.

Mr. Ernest N. Jennison is now connected with the construction department of the Great Western Sugar Company, and will be located at the Fort Collins, Colorado, factory of that concern for the present.

Mr. John G. Roberts has resigned his position as head of the patent department of the Western Electric Company, to take up general work as consulting electrical engineer and expert in patent cases.

Mr. Paul J. MacCutcheon has accepted a position with the M. B. Foster Electric Company, contracting engineers, of New York and Boston, and is located at the home office, 109 West 26th Street, New York City.

Mr. H. P. Myers has left the F. Bissell Company, of Youngstown, Ohio, where he held the position of foreman of winding department, and is now chief electrician for the Marion Steam Shovel Company, Marion, Ohio.

Mr. R. C. House, formerly superintendent for the M. W. Forney Company, 1 Madison Ave., New York City, has associated himself with the Safety Insulated Wire & Cable Company, New York, in their sales department.

Mr. P. A. Morse has recently been transferred from the St. Louis office of the Western Electric Company, to the general headquarters of the company at Hawthorne, Illinois, as manager of industrial motor sales.

Mr. David D. Gibson has resigned his position as engineer in the U. S. Indian Service and is now engaged in construction work for Messrs. Lyde and Kyser, consulting and contracting engineers, Birmingham, Ala.

Mr. C. E. Heston, who had charge of the installation of fire control apparatus in the forts on Puget Sound, has been transferred to Manila, P. I., as engineer in charge of fire control installations in the Philippine Islands.

Mr. George C. Heckman, formerly with the General Electric Company, in charge of power and equipment at the Fort Wayne Lamp Works, has accepted the position of manager of the San Luis Gas and Electric Company, San Luis, Obispo, Cal.

Mr. Wilbur H. Young, formerly sales engineer for the General Storage Battery Company, has been appointed general manager of the M. F. Fleck Company; electrical engineers and contractors, 101 Beekman Street, New York City.

Mr. Lyman Shepard has severed his connection as superintendent of electric lights and water works at Edenton, N. C., to accept the position of superintendent of the Welch Water, Light and Power plant at Welch, West Virginia.

Mr. W. N. Ryerson, for four years superintendent of the Ontario Power Company of Niagara Falls, has been appointed general manager of the Great Northern Power Company, Duluth, Minn. Mr. Ryerson assumed his new duties January 1, 1909.

Mr. George Wolf has severed his connection with the Western Electric Company, as assistant in the circuit laboratory, and joined the engineering staff of the Duplex Metals Company, having offices at 208 Fifth Avenue, New York City.

Mr. H. L. Stephenson, for the past two years district engineer in Cincinnati, for the Westinghouse Electric and Manufacturing Company, has been transferred to the sales department of the same company, with headquarters at Buffalo, N. Y.

Mr. G. K. Selden, formerly with the Chesapeake and Potomac Telephone Company as construction engineer for the Washington division, is now plant supervisor of the Southern Bell Telephone and Telegraph Company, with headquarters at Atlanta, Georgia.

Mr. C. E. Armstrong, formerly superintendent of light, steam, and heat, Danville, Ill., has been transferred to Cairo, Ill., as general superintendent over the Cairo Electric & Traction Company, Cairo City Gas Company, and Cairo & St. Louis Railway Company.

Mr. Harry W. Eastwood has lately been transferred from the Cleveland sales office of the Electric Controller and Manufacturing Company, to the Chicago office of the company, with headquarters in the Merchants Loan and Trust Building, 135 Adams Street.

Mr. J. E. Wickstrom, of the Seattle, Tacoma Power Company, Seattle, has been transferred to Everett, Washington, in the capacity of general foreman, and has charge of the sub-station, operation and construction, and the transmission line from Everett to Snoqualmie Falls.

Mr. C. W. Hutton has become associated with the Great Western Power Company as engineer of operation and maintenance, with headquarters at Sacramento, Cal. Mr. Hutton was formerly assistant manager of the Sacramento Electric, Gas and Railway Company.

Mr. Louis F. Leurey, formerly with Sanderson and Porter, on the Nine Mile Bridge development in Spokane, Washington, is now engaged in electrical construction work for the Union Construction Company on the Stanislaus electric power development in Calveras County, California.

Mr. Howard L. Beach has accepted the position of chief electrician of the Pennsylvania Coal and Coke Company, Cresson, Pa. He will have charge of all operating machinery, including power plants, transmission lines, and steam, air, and electrically driven mine machinery.

Mr. Loren Emery, until recently with the Stone & Webster Engineering Corporation, of Boston, Mass., is now with the Cleve-Mor Engineering and Construction Company, 413 Citizens Building, Cleveland, Ohio. He will have charge of all the engineering work of the company.

MR. J. P. MOORE, formerly electrical engineer for the Keystone Construction Company of Indianapolis, Ind., is now connected with the Des Moines Electric Light Company of Des Moines, Iowa, as superintendent of distribution. Mr. Moore assumed his new duties January 1, 1909.

MR. G. F. CHELLIS, electrical engineer for J. G. White & Company, has been transferred from Hatfield, Wis., to Dummer, Vermont, to supervise the installation of electrical apparatus at the 20,000 kw. hydroelectric plant of the Connecticut River Power Company, now in course of construction.

MR. C. H. CLARK, assistant advertising manager of the Western Electric Company, has changed his residence from Chicago, to 19 Davis Avenue, East Orange, New Jersey, the publicity department of the Western Electric Company having been transferred from Chicago to the New York offices of the company.

MR. THEODORE G. SEIXAS has been elected vice-president of the Pacific Traction Company, with offices at Tacoma, Washington. Mr. Seixas is to have charge and reorganize the several companies controlled by the eastern interests he represents, including water powers in the State of Washington.

MR. A. V. YOUENS, who has been engaged for the past three years by the E. I. du Pont de Nemours Powder Company, making powder tests and determinations at their California plants, recently completed this work, and in company with his wife is now visiting his father, Mr. A. G. Youens, Galveston, Texas.

MR. W. W. BRADFIELD, of London, who in April, 1902 was appointed electrical engineer to the Marconi Wireless Telegraph Company of America, resigned in June, 1908 and was appointed the same day deputy manager of Marconi's Wireless Telegraph Company, Ltd., and the Marconi International Marine Communication Company, Ltd.

MR. WALTER J. JONES, who for the past three years was associated with the late Dr. F. A. C. Perrine, will continue the consulting engineering business of Dr. Perrine, at the old offices, 60 Wall Street, New York City. Mr. Jones is carrying through to completion the work that Dr. Perrine had on hand at the time of his death.

MR. J. D. KENNEDY, who until October 1908 was associated with the telephone engineering department of the Western Electric Company in New York and Chicago, the last year as engineer-in-charge at the Chicago works, has been appointed manager of the Philadelphia works of the same company. He assumed charge in November last.

MR. J. W. PUTNAM has given up his position as assistant engineer of the Toronto & Niagara Power Company, to accept the post of general manager of the recently incorporated firm, Overhead and Underground Construction Company. Mr. Putnam's office is in the new United States Express Company's building, 2 Rector Street, New York City.

MR. A. A. TIRRILL has resigned his position in the engineering department of the General Electric Company at Schenectady, N. Y., to devote his time to the manufacture of electrical supplies and specialties, having recently organized and incorporated for this purpose a company known as the Tirrill Manufacturing Company, at Schenectady, N. Y.

MR. L. H. LATHROP, for some years past superintendent of the electrical testing bureau of the Milwaukee Electric Railway and Light Company, Milwaukee, Wisconsin, has resigned his position to accept an appointment as assistant inspector of electric service on the engineering staff of the Wisconsin Board of Assessment and Railroad Commission, Madison, Wisconsin.

The position of contract engineer was created by the North Shore Electric Company on January 1, 1909, and Mr. C. W. Pen Dell, who has been electrical engineer for the company for the last two and a half years, has been assigned to the new position. Mr. Pen Dell will take care of the engineering details in securing large power customers and connecting them to the company's lines.

Robert Hawxhurst, Jr., having recently completed his examination of the Mino silver mines and the Santa Jovita copper mines in the Province of Tarapaca, Chile, is now engaged in examining a project for the transmission of electric power twenty-five miles, from the source of the Loa River to the mines of the Collahuasi district. He remains in Chile as general manager of the Poderosa Mining Company of Collahuasi.

Mr. Walter S. Moody, chief engineer of the transformer department of the General Electric Company for the past fifteen years, has moved his headquarters from Schenectady to Pittsfield, the transformer production of the General Electric Company, which for several years has been sub-divided between the Schenectady, Lynn and Pittsfield works, having been concentrated at the Pittsfield works of the company.

Mr. F. H. Knox, who was chief engineer in the construction of a 37 mile interurban line for the Boise and Interurban Railway Company, at Boise, Idaho, operating the line for one year after its completion, is now vice-president and general manager of the Spartanburg Railway, Gas and Electric Company, and general manager of the Electric Manufacturing and Power Company, these two companies having been consolidated on August 1, 1908. Mr. Knox's headquarters are at Spartanburg, S. C.

Mr. C. O. Mailloux, of New York, who with Richard O. Heinrich represented the Institute at the International Electrical Congress at Marseilles, was retained, while abroad, to advise a financial syndicate in connection with important projects involving electric traction, electric transmission, power, etc. He made investigations in Switzerland and France, and on his return to Marseilles started on a trip by water to various cities on the Mediterranean. He visited Constantinople and points further east. He returned to Paris late in November and delivered a course of lectures in French on electric train movement, with especial reference to the technical study of electric traction problems, methods of predetermination, and also a special lecture on the electrification of steam roads. The paper presented by him at Marseilles, entitled " Sur la Definition et la Mesure Industrielles de l'Acceleration ", created something of a sensation by its bold and vigorous defense of the American unit of measure, the mile per hour per second, and especially by its attack on the European units, the foot per second per second, from the mathematical side which has always hitherto supposed to be its stronghold. Some of his colleagues, desirous of hearing further discussion from the American point of view, requested him to repeat portions of the course of lectures given by him at the University of Pennsylvania and at Columbia University, to a special audience composed of engineers and others specially interested in electric traction and electrification. A committee was appointed to make the arrangements and issue the invitations.

Library Accessions

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Wittig, P. Zur Eröffnung der Untergrundbahn nach Westend. Berlin, 1908.

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Beggs, James & Co., 109 Liberty St., N. Y. City, Blackburn-Smith Feed Water Filter & Grease Extractor, n.d.

Crocker-Wheeler Company, Ampere, N. J. Belt Type Alternating Current Generators (Bulletin no. 95, Sup. I). D.C. Switchboard Panels, Type 3 (Bulletin no. 106). Direct Current Lighting & Power Generators (Bulletin no. 107). Engine Type Alternating Current Generators (Bulletin no. 108). Generating Sets with Type " D " Engines (Bulletin no. 109).

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Vol. XXVIII **March, 1909** No. 3

March Meeting, A. I. E. E.

The two-hundred and thirty-fifth meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineers' Building, 33 West Thirty-ninth Street, New York City, on Friday, March 12, 1909, at 8 o'clock p.m. Mr. Barton R. Shover, electrical engineer of the Indiana Steel Company, will present a paper entitled "The Industrial Application of the Electric Motor as Illustrated in the Gary Plant of the Indiana Steel Company." The paper is printed in this issue of the PROCEEDINGS. in Section II. It deals with the many novel features of the electrical installations in the Gary plant, undoubtedly the largest steel-making plant in the world. One of the most interesting features of this plant is the electrical equipment of the rail-mill. This mill has a capacity of 4,000 tons of finished rails every 24 hours. The rails are rolled directly from the ingot without reheating, the roll-trains being direct-connected to the largest induction motors ever made. Some of these motors are of 2,000 h.p. capacity; others have a capacity of 6,000 h.p. All of the motors are operated at a pressure of 6600 volts.

Conservation of Natural Resources—A Joint Meeting of the Four National Engineering Societies, New York, March 24, 1909

On Wednesday evening, March 24, 1909, the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, will hold a joint meeting in the auditorium of the Engineers' Building, New York. The topic to be discussed is the Conservation of Natural Resources. A representative from each society will present a paper in regard to some specific feature of this vital economic problem. All four societies have announced the names of their representatives and the titles of the papers to be presented. The authors and titles are:

1. American Society of Civil Engineers—"The Conservation of Water." By John R. Freeman.
2. American Institute of Mining Engineers—" The Conservation of Natural Resources by Legislation." By Rossiter W. Raymond.
3. American Society of Mechanical Engineers—" The Waste of Our Natural Resources by Fire." By Charles Whiting Baker.
4. American Institute of Electrical Engineers—" Electricity and the Conserva-

tion of Energy." By Lewis B. Stillwell.

Owing to lack of time there will be no discussion on these papers. No resolutions will be adopted, nor any action taken which would commit any or all of the societies to the endorsement of views presented either in the paper or in the discussion communicated afterward. About ten days before the meeting each society will send a notice to its own members; this notice will state more fully the object of the meeting, and should be considered as an invitation to any member to submit a written discussion on the papers.

The Chairman of the A. I. E. E. Committee on Conservation of Natural Resources is Mr. Henry G. Stott, 600 West 59th Street, New York.

April Meeting, A. I. E. E.

The April meeting of the American Institute of Electrical Engineers will be held in New York City, April 9, 1909. This meeting will be under the auspices of the HIGH-TENSION TRANSMISSION COMMITTEE. The following papers will be read:

" High-Voltage Transformers and Protective and Controling Apparatus for Outdoor Installation." By Mr. K. C. Randall, engineer in charge of transformer design, Westinghouse Electric and Manufacturing Co.

" Condenser Type of Insulation for High-Tension Terminals." By Mr. A. B. Reynders, engineer with the Westinghouse Electric and Manufacturing Co.

The former deals with the design of high-voltage transformers, oil switches, and lightning-arresters for installation outdoors, thus saving the cost of a building and doing away with the expense of high-voltage wall outlets.

The latter has to do with a new development in the design of high-voltage terminals and bushings, which results in a much smaller and more reliable bushing than those which have been in use heretofore, and which lends itself readily to the construction of bushings for outdoor apparatus.

Both of these papers should be of great interest to those having to do with transmission matters.

Minutes of February Meeting of the Institute

The two hundred and thirty-fourth regular meeting of the American Institute of Electrical Engineers, was held in the auditorium of the Engineers' Building, 33 West thirty-ninth street, New York, Friday, February 19, 1909. President Ferguson called the meeting to order at 8:00 p.m.

The Secretary announced that at the meeting of the Board of Directors held during the afternoon there were 88 Associates elected. The directors present at the meeting were: Messrs. President Louis A. Ferguson, of Chicago, Ill. Vice-presidents C. C. Chesney, Pittsfield, Mass.; Calvert Townley, New Haven, Conn. Managers P. M. Lincoln, Pittsburgh, Pa.; Paul Spencer, Philadelphia, Pa.; W. S. Murray, New Haven, Conn.; P. H. Thomas, Montclair, N. J.; D. B. Rushmore, Schenectady, N. Y.; W. G. Carlton, New York; H. E. Clifford, Boston, Mass.; Secretary Ralph W. Pope, New York.

The Associates elected were as follows:

AMES, AZEL, Signal Engineer, N. Y. C. & H. R. R.R., New York City; res., 17 Fairfield Pl., Yonkers, N. Y.

AOYAGI, EIJI, Professor of Electrical Engineering, Kyoto Imperial University, Kyoto, Japan.

ATKINSON, RALPH WALDO, Assistant to Chief Engineer, Standard Underground Cable Company, Pittsburg, Pa.

BAILEY, CARROLL E., Electrical Engineer, J. G. White & Co., 43 Exchange Place, New York City.

BAKER, JAMES NELSON, Electrical Engineer, Westinghouse Electric & Mfg. Co., Stamford, Conn.

BARKER, CHARLES ANTHONY, Lamp Agent, Westinghouse Electric & Mfg. Co., Atlanta, Ga.

BARRETT, WILLIAM E., Gas Engineer, J. G. White & Co., 43 Exchange Pl., New York City.

Bart, John George, Assistant Superintendent, Ellsworth Colleries Co., Cokeburg, Pa.

Bartlett, Edwin Ball, Engineer and Salesman, Allis-Chalmers Co.; res., 24 S. State St., Salt Lake City, Utah.

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Burch, Edward Charles, Foreman Inside Meter Dept., Allegheny County Light Co., Pittsburg, Pa.

Carbo, Luis Alberto, Chief Engineer, Guayaquil Sewer and Water Board, Guayaquil, Ecuador, S. A.

Chamberlin, Egbert C., Telegraph Operator, N. Y. Fire Dept., 451 E. 176th St., New York City.

Chapin, Adelbert Lymon, Asst. Chief Electrician, S. C. Ry. Co.; res., 7200 Woodlawn Ave., Chicago, Ill.

Clark, Charles Conrad, Salesman, Kilmer & Pullen, for Swedish General Electric; res., 877 Hornby St., Vancouver, B. C.

Clark, Robert Joseph, Meter Expert, Leadville Light & Power Co., Leadville, Colo.

Clinch, Edward Sears, Jr., President, M. B. Foster Elec. Co., 109 W. 26th St., New York City.

Colburn, Avery Reeves, Draftsman, Missouri River Power Co., Helena, Montana.

Cox, Thomas James, Foreman in Construction Dept., Indiana Steel Co., Gary; res., Tolleston, Ind.

Crisson, George, Instructor in Electrical Engineering, Stevens Institute of Technology; res., 720 Park Ave., Hoboken, N. J.

de la Rochette, Eugene Louis Georges, de Portanier, Electrical Engineer, Westinghouse Electric & Mfg. Co., New York City.

Doremus, Wyatt Swift, Consulting Engineer, 50 Church St.; res., 383 Central Park West, New York City.

Duncan, Andrew Jackson, Jr., Secretary and General Manager, Citizens Ry. & Lt. Co., Fort Worth, Texas.

Duncan, William G., Assistant Superintendent, Lighting Dept., The N. & P. Traction Co., Norfolk, Va.

Field, Forrest Whipple, Student, University of Iowa, Iowa City, Ia.

Fitting, Ralph Ulf, Operating Dept., Electric Bond & Share Co., 62 Cedar St., New York City.

Foster, Edmund, Foreman, Meter Testing Dept., Norfolk & Portsmouth Traction Co.; res., 705 29th St., Norfolk. Va,

Frank, Eugene, Electrical and Mechanical Contracting Engineer, 22 E. 21st St.; res., 209 W. 127th St., New York City.

Grover, Marcus Allen, Consulting Electrical and Mechanical Engineer, Birmingham, Ala.

Hall, Arthur John, Road Engineer, Ry. Const. Dept., Westinghouse Electric & Mfg. Co., Stamford, Conn.

Hall, Earnest, Rotary Operator, Northwestern Elevated Railroad; res., 1139 Montana St., Chicago, Ill.

Harnden, John Davis, Foreman, Turbine Testing Dept., General Electric Co.; res., 1022 State St., Schenectady, N. Y.

Hart, Leon O., Electrical Engineer, The Driver-Harris Wire Co., Harrison, N. J.

Harvey, Reuben Henry, Contract Engineer, Dick, Kerr & Co., London, England; res., Bahia, Brazil.

Heath, Stephen T., Operating Statistician, J. G. White & Co., New York City; res., 116 Henry St., Brooklyn, N. Y.

Hegarty, George Daniel, Asst. Manager, Ft. Halifax Power Co., and Messalonskee Electric Co., Waterville, Me.

Hinckley, William G., Chief Engineer, Hartford Retreat; res., 30 Washington St., Hartford, Conn.

Hodgson, Francis Marion, Superintendent, Winona Telephone Company res., Plymouth, Ind.

Hovde, Lorentz Edvard, Foreman, J. G. White & Co.; res., 113 W. King St., Winona, Minn.

Hughes, Charles Wesly, City Electrician; res., 204 Scott St., Joliet, Ill.

Ito, Ichiro, Electrical Engineer, Siemens Schuckert Electric Co.; res., 9 Ichishome, Tamachi, Asakusa Ku, Tokio, Japan.

Ives, Robert Stephen, Superintendent, C. & M. E. R.R. Co., Highwood; res., Highwood Park, Ill.

Jacobs, Ralph C., Tester, Crocker-Wheeler Co., Ampere, N. J.; res., 43 N. Brighton Ave., E. Orange, N. J.

Jacobus, Robert Fulton, Assistant Engineer, American Tobacco Co., 111 Fifth Ave., New York City; res., Ridgefield, N. J.

Jakobsen, Bernhard Faaborg, Asst., Electrical Engineering, U. S. Reclamation Service, Roosevelt, Arizona.

Jansen, Edgar W., Chief Electrician, Illinois Central Railroad Co.; res., 197 Oakwood Blvd., Chicago, Ill.

Johnson, Clarence Anthony, Asst. Professor in Electrical Engineering and Physics, Kansas State University, Lawrence, Kan.

Jones, George Harvey, Electrician, Girard Trust Co., Philadelphia, Pa.

Krouse, Charles Stanley, Asst. Subway Engineer, C. D. & P. Tel. Co.; res., 223 5th St., Aspinwall, Pa.

Leite, Lysanias de Cerqueira, Estacas de S. Francisco Xavier, Rio de Janeiro, Brazil.

Ludlow, George Richard, Assistant Superintendent and Estimator, Blackall & Baldwin Co.; res., 481 E. 171st St., New York City.

MacLean, Daniel Wallace, Student, University of Maine, Orono, Me.

McIntyre, Arthur Bender, Student Engineer, General Electric Co.; res., 138 Parkwood Blvd., Schenectady, N. Y.

MacIlraith, Evan John, Instructor, Cornell University; res., 302 Mitchell St., Ithaca, N. Y.

McMullen, Thomas Edgarton, Jr., Foreman Electrician, The Moran Co.; res., 923 E. 73d St., Seattle, Wash.

Moore, Leon J., Cable Tester, Home Tel. & Tel. Co.; res., 624 W. 10th St., Los Angeles, Cal.

Morris, John M., Engineer-Salesman, Westinghouse Electric & Mfg. Co., Los Angeles, Cal.

Mosiman, Levi, Salesman, Western Electric Co.; res., Morton, Ill.

Oana Hideichi,, Chief Electrical Engineer, Asano Portland Cement Co., Fukagawaku, Tokio, Japan.

Oppenheimer, Ferdinand, Engineer in Bureau of Testing, United Railways and Electric Co.; res., 2103 15th St., Baltimore, Md.

Paca, William Smith, Engineer and General Manager, Petroleum Telephone Co., Oil City, Pa.

Parker, George A., Mechanical-Electrical Engineer, Brown Hoisting Machinery Co.; res., 1341 E. 82d St., Cleveland, O.

Pastoriza, Hugh, Engineer, Telluride Power Co., Provo, Utah.

Plum, Verne, Student, University of Iowa, Iowa City, Ia.

Ralston, Louis Chapman, Mechanical and Electrical Engineer, 720 Foxcroft Bldg., San Francisco, Cal.

Ricksher, Theodore, Student, College of Applied Science, University of Iowa, Iowa City, Ia.

ROBINSON, CONWAY. Designing Engineer, General Electric Company, Schenectady, N. Y.

SCHOEL, WILLIAM AMILE, Graduate Student, E.E., Oregon Agricultural College Corvallis, Oregon.

SCOTT, HOWARD HAMILTON, Electrical Engineer, Allis-Chalmers-Bullock Ltd Montreal, P. Q.

SHAW, HERBERT RUEL, Tester, General Electric Co.; res., 114 Ave. B, Schenectady, N. Y.

SMITH, OLIVER TODD, Selling Engineer, Westinghouse Electric & Mfg. Co., 165 Broadway, New York City.

STEARNS, WILLIAM GORDON, Salesman, J. A. Roebling's Sons Co., Los Angeles, Cal.

STONE, STUART RUTHERFORD, Electrical Testing, Long Island Railroad Co.; res., 918 Eighth Ave., Brooklyn, N. Y.

SUNDERLIN, EUGENE A., General Manager & V.P., Grand Junction Electric Ry. Co., Colorado Springs, Colo.

VOGEL, JULIUS CHRISTIAN, Stevens Institute of Technology, Hoboken, N. J. res., 112 Sherman Pl., Jersey City, N. J.

VOSS, MAXWELL HUGHES, Electrical Engineer, Cia. Carbonifera de Lampacitos, S. A.; res., Baluarte, Coah, Mex.

WATSON, JAY R., Tester and Wireman, Westinghouse Electric & Mfg. Co., Stamford, Conn.

WEBSTER, LOUIS DAVID, Student, Western Electric Co.; res., 853 So. Lawndale Ave., Chicago, Ill.

WHITMORE, JESSE DWIGHT, General Manager, Union Stock Yards Company, Grand Island, Neb.

WOODWARD, CLIFFORD DEWEY, Chief Electrician, Smelting Dept., Boston and Montana C. C. & S. M. Co., Great Falls, Montana.

WREAKS, HUGH TOLER, Secretary, The Wire Inspection Bureau, 29 W. 39th St., New York City.

YOUNG, CHARLES EDWIN, Division Supt. Pacific Gas & Electric Co., San Francisco, Cal.; res., Marysville, Cal.

The secretary announced further that the following Associates were transferred to the grade of Member:

STANDEN LEONARD PEARCE, City Electrical Engineer, Electricity Works, Manchester, England.

HARRY ARCHER HORNOR, Electrical Engineer, New York Shipbuilding Company, Camden, N. J.

ALLAN B. FIELD, Electrical Engineer. Allis-Chalmers Company, Milwaukee.

EDWIN FITCH NORTHRUP, Secretary, The Leeds and Northrup Co., Philadelphia, Pa.

A paper entitled, "Prime Movers" by Mr. Charles P. Steinmetz, was then read by Mr. Ernst J. Berg, consulting engineer of the General Electric Company, Schenectady, N. Y. [Owing to illness Dr. Steinmetz was prevented from presenting the paper in person.] The paper was discussed by Messrs. C. E. Lucke, H. W. Longwell, D. B. Rushmore, Calvert Townley.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before April 1, 1909.

8299 Rahmberg, H. M., Stockholm, Swe
8300 Roberts, J. T., Biltmore, N. C.
8301 Bartholomew, H. C., Phila., Pa.
8302 Young, R., Lake Bantzen, B. C.
8303 Libby, M. M., San Francisco, Cal.
8304 Morgan, H. H., Chicago, Ill.
8305 King, J. C., St. Catharines, Ont.
8306 Barber, H. C., Toronto, Ont.
8307 McCarthy, J. A., Elizabeth, N. J.
8308 Pocock, M. A., St. Paul, Minn.
8309 St. John, Edw., Brooklyn, N. Y.
8310 Bryant, Roy B., Little Rock, Ark.
8311 Christie, W. F., Lynn, Mass.
8312 MacDonald, Thos., New York City.
8313 Cullinane, P. F., New Orleans, La.
8314 Danielson, W.A., Ft. Worden, Wash.
8315 Johns, A. N., Tacoma, Wash.
8316 Plank, Ray, Tacoma, Wash.
8317 Lamberton, B. P., Jr., Washington D. C.

8318 Crawford, P. O., Manton, Cal.
8319 Wardwell, A. S., Brooklyn, N. Y.
8320 Rickards, A. E., Avalon, Pa.
8321 Wakeman, H. R., Portland, Ore.
8322 Wilson, J. N., Toronto, Canada.
8323 Robb, Wm. A., Portland, Ore.
8324 Stare, Burton R., Seattle, Wash.
8325 Turlay, C. C., Vancouver, Wash.
8326 Antoine, L. M., Portland, Ore.
8327 Burghduff, A. E., Portland, Ore.
8328 Burns, A. E., Portland, Ore.
8329 Eliot, E. M., Portland, Ore.
8330 Guldmeister, O. P., Portland, Ore.
8331 Hamilton, W. M., Portland, Ore.
8332 Higgins, G. E., Portland, Ore.
8333 Jenks, L. H., Carthage, N. Y.
8334 Kennedy, D.R., Lake Bantzen, B.C.
8335 Quimby, Lewis, Portland, Ore.
8336 Breese, J. E., Lima, Ohio.
8337 Crouse, D. E., Annapolis, Md.
8338 Burnett, A. H., Richmond, Cal.
8339 Gaskin, Ivan H., Dorchester, Mass.
8340 Hall, C. E., Des Moines, Iowa.
8341 Haskell, D., Durango, Mexico.
8342 Mitchell, L. La C., Pittsburgh, Pa.
8343 Bleckwedel, G. H., Brooklyn, N. Y
8344 Cadwell, R. L., Warren, Ariz.
8345 Cargill, W. N., Lynn, Mass.
8346 Gent, Rufus, New York City.
8347 Hershey, H. B., New York City.
8348 Jewett, F. N., St. Louis, Mo.
8349 Kellett, W. P., Brantford, Ont.
8350 Kenney, T. A., Albany, N. Y.
8351 Ball, S. M., Atlanta, Ga.
8352 Bean, C. R., Portland, Ore.
8353 Edwards, J. B., Atlanta, Ga.
8354 Kennedy, H. H., Syracuse, N. Y.
8355 Wagner, F. C., Terre Haute, Ind.
8356 Wood, E. M., Toronto, Ont.
8357 Baylor, N. R., San Francisco, Cal.
8358 Hamilton, T., Chambersburg, Pa.
8359 Morse, John, Montreal, Canada.
8360 Klonower, A. A., Philadelphia, Pa.
8361 Clark, J. R., Chicago, Ill.
8362 Egg-Sieberg, H., Bale, Switzerland
8363 Glynn, C. V., Hershey, Pa.
8364 Friendly, H. M., Portland, Ore.
8365 Harley, E. B., Portland, Ore.
8366 Hazelton, H., Brooklyn, N. Y.
8367 Hess, F. M., Bishop, Cal.
8368 Hirschberg, H. M., New York City.
8369 Peterson, E. B., Des Moines, Iowa.
8370 Smith, Tracy, Waterbury, Conn.
8371 Viellard, L. F., Ozone Park, L. I., N. Y.
8372 Dawes, L. M., Trenton, N. J.
8373 Frazer, H. W., Wilmington, Del.
8374 Hewson, Wm. G., Wilkinsburg, Pa
8375 Horgan, J. G., Joplin, Mo.
8376 Kifer, E. H., Madison, Wis.
8377 Swallow, J. G. W., Brooklyn, N. Y.
8378 Arnott, R. F., Montclair, N. J.
8379 Fink, Howard, York, Pa.
8380 Gale, Walter, Jr., Phila., Pa.
8381 Hicks, L. J., Schenectady, N. Y.
8382 Miller, E. W., Philadelphia, Pa.
8383 Schoepf, A. W., Spokane, Wash.
8384 Shartle, S. G., Ft. Monroe, Va.
8385 Stephenson, R., Des Moines, Iowa.
8386 Talpey, A. H. E., Dorchester, Mass
8387 Coffin, S. M., Mobile, Ala.
8388 Curtis, H. L., International Falls, Minn.
8389 Hayes, G. B., Detroit, Mich.
8390 Iyengar, S. D. S., Bangalore City, India.
8391 Hussey, C. E., Chester Park, L. I.
8392 Ring, Samuel, Portland, Ore.
8393 Buswell, J. M., Oakland, Cal.
8394 Clark, P. L., Baltimore, Md.
8395 Cole, C. D., Rice Lake, Wis.
8396 Orr, C. W., Tooele, Utah.
8397 Walker, E. F., New Orleans, La.
Total, 98.

Applications for Transfer

Recommended for transfer by the Board of Examiners February 19, 1909. Any objection to these transfers should be filed at once with the secretary.

Charles Frederick Lacombe, Chief Engineer, Light & Power, Dept. of Water Supply, Gas & Electricity, New York City.

Worrall E. S. Temple, Associate Professor of Electrical Engineering, University of Pennsylvania, Phila, Pa.

Johann Emil Leonarz, Electrical Engineer, Mexican Light & Power Company, Mexico City.

Henry Rufus King, Chief Engineer, Power Apparatus Dept., Western Electric Company, Hawthorne, Ill.

Robert Sibley, Consulting & Hydraulic Engineer, Missoula, Montana.

Notes on Transmission Practice in the Northwest[*]

BY MAGNUS T. CRAWFORD

The object of this paper is to assemble in a form convenient for comparison and discussion the various systems of high-tension transmission in the Northwest, and to discuss the relative merits and defects of each system. As each section of the country has its own characteristic set of climatic and industrial conditions, transmission practice features that are economical and good practice in one section may be more or less unsuitable in another section. For this reason this discussion will be confined to practice in the Pacific Northwest. As typical examples, a number of systems will first be briefly described, and discussed in detail later.

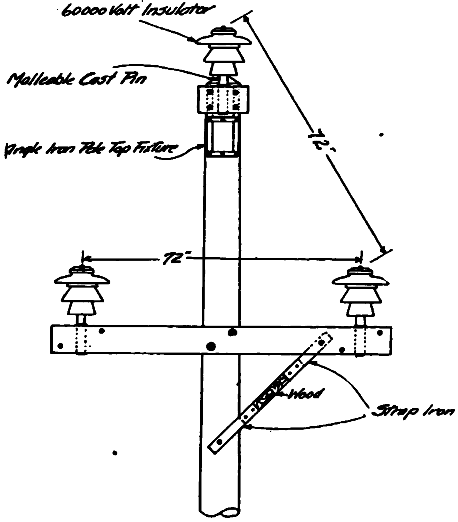

FIG. 1
POLE TOP CONSTRUCTION
ELECTRON LINE
PUGET SOUND POWER CO.
55000 VOLTS, 3φ.

Puget Sound Power Company. This company operates a hydroelectric station at Electron, Washington, on the Puyallup River. Two 55,000-volt, three-phase lines run parallel to Bluffs, where they separate; one goes to Tacoma, the other to Seattle, following the Puget Sound electric railway right-of-way. These lines were built in 1903 and have the construction shown in Fig. 1. The wire is 0000 B. & S., 19-strand, semi-hard-drawn copper, except from Bluffs to Tacoma, where it is 0 B. & S. solid copper. The insulators are standard four-piece, 60,000-volt porcelain on galvanized malleable cast-iron pins of a design similar to a pipe pin. Part of this line was equipped with wooden pins for trial, but the iron pins have proved more satisfactory. The length of the Seattle line is about 50 miles, that of the Tacoma line about 30 miles. At the generating and substations each line is controlled by a switchboard panel equipped with three ammeters, one automatic, remote-control, oil circuit-breaker, and one overload time-limit relay. The circuit-breakers are electrically operated oil-switches in concrete compartments. At Bluffs disconnecting pole-switches are used for paralleling and cross-connecting the lines, as shown in Fig. 3. A second line of solid copper, known as the interurban line, runs parallel and on the opposite side of the railway, feeding into sub-stations located at Massachusetts street, Seattle, and at Kent, Milton and Tacoma. The size of the wire is 1 B. & S. solid copper from Seattle to Georgetown, 4 B. & S. from Georgetown to Milton, and 1 B. & S. from Milton to Tacoma. This line is constructed as shown in Fig. 2, and has been operated at 55,000 volts for the last few months. It was originally built for this voltage, but until recently has been operated at 30,000 volts. Although the spacing between wires is rather small, no trouble has been encountered, as the spans are not over 100 ft.

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[*] A paper presented at a meeting of the Seattle Section of the American Institute of Electrical Engineers, Seattle, Washington, December 19. 1908.

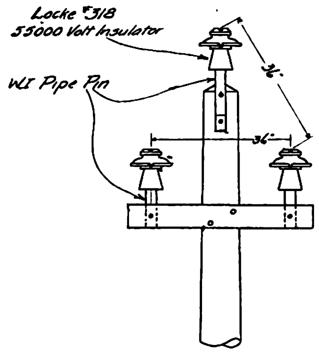

Fig. 2
Pole Top Construction
Interurban Line
Puget Sound Power Co.
55000 Volts, 3 ϕ.

This company reports practically no trouble from electrical failures of insulators on either line, as all insulators were tested before they were accepted. The only trouble has been from softening and burning of wooden pins. These pins have been replaced by wrought-iron pipe pins, and no difficulty has arisen since.

Seattle-Tacoma Power Company, Snoqualmie Falls System. The system of this company has been in operation for 10 years, and is the oldest high-tension transmission system on Puget Sound. Some of the apparatus installed is of a type now obsolete, but the plant is being gradually rebuilt, and much of it is new and modern. The main generating station is at Snoqualmie Falls. As originally built this system consisted of a double-pole line from Snoqualmie Falls to Renton, and single-pole lines from Renton to Tacoma and from Renton to Seattle. Each pole-line carried two three-phase, three-wire, 30,000-volt circuits arranged as shown in Fig. 4, with a space of 30 in. between the wires. The wires were of aluminum with a cross-section of approximately 65,000 cir. mils. The insulators were triple petticoat imperial porcelain of the Redlands type. After a few years' operation, this system was rebuilt with larger wires and a larger space between them. Various difficulties were encountered with the 30-in. spacing—large birds, sticks, bale-wire, etc., became entangled in the wires, causing short-circuits. A wire once burned off was apt to whip around and short-circuit the others as well.

In 1903 the lines were reconstructed with only one circuit per pole line, giving a 9-ft. by 6.5 ft. flat triangular spacing as shown in Fig. 5, by simply removing the top cross-arm and putting on a pole-top pin. A new pole-line was built from Renton to Tacoma and one from Renton to Seattle, with a 7-ft. triangular spacing as shown in Fig. 6. The same insulators were used, as they had proved satisfactory. This gave two separate pole lines from Renton to both Seattle and Tacoma. On these lines a seven-strand aluminum cable of 00 B. & S. gauge was used, and from Renton to the falls each line was of seven-strand aluminum 0000 B. &. S. gauge. The reconstructed system has now been in operation about five years, and the wide spacing has given almost entire freedom from trouble due to short-circuits between the wires. As shown on the sketch, the insulator pins are of locust wood. About a year ago these pins began to give trouble from burning and softening. They were replaced on curves and important points by malleable cast-iron pins.

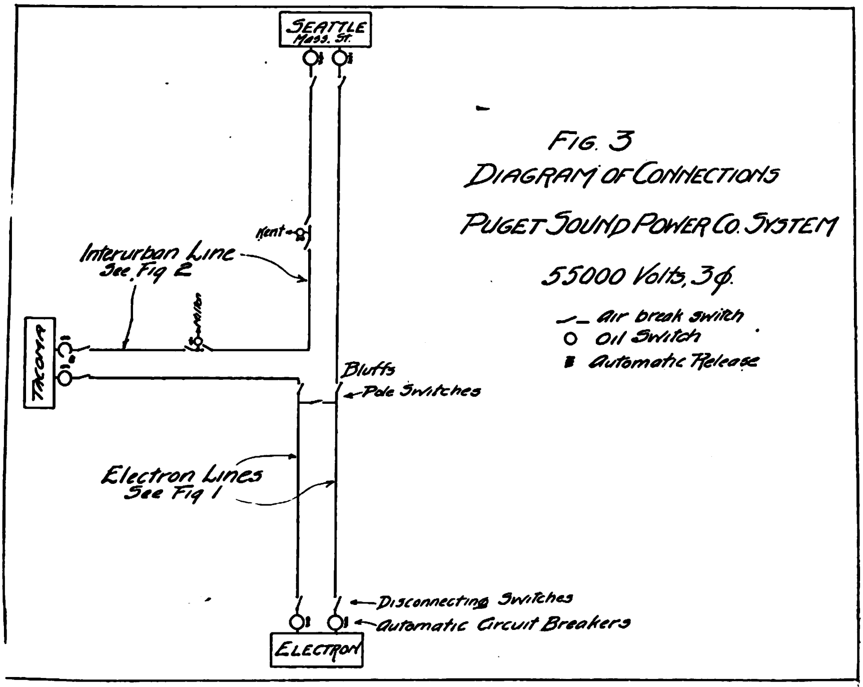
Seattle Mass. St.
Kent
Interurban Line See Fig 2
Tacoma
Bluffs
Pole Switches
Electron Lines See Fig 1
Disconnecting Switches
Automatic Circuit Breakers
Electron
Air break switch
O Oil Switch
Automatic Release

FIG. 3 DIAGRAM OF CONNECTIONS PUGET SOUND POWER CO. SYSTEM 55000 Volts, 3φ.

In 1906 this company built a single pole-line from Snoqualmie Falls to Everett, with the construction shown in Fig. 7. The line was of No. 4 medium-hard-drawn copper, and the insulator of shape similar to the imperial white insulator on the main lines, but made of brown porcelain. Malleable-iron pins were used throughout, being fastened to a channel at the pole-top as shown. The porcelain was not of so good a quality as that in the imperial white insulators, and occasional trouble resulted from insulators shooting through the head to the pin when a ground came on the system. In 1908 this line was reconstructed for 60,000 volts in order to carry the increased load, and as the first step in the change of the entire system to 60,000 volts. The new construction is shown in Fig. 8. There has been no trouble of any nature, though the line has been in service several months.

The general switching arrangement is shown in Fig. 9. There is no automatic release anywhere on main lines, as this company believes such apparatus to be a hindrance rather than a help. This will be discussed more fully later. The switches used at the falls are non-automatic oil switches in compartments. Those at Renton, Seattle, and Tacoma are tank switches, consisting of a double-break switch immersed in a separate tank of oil for each leg of the line. They are controlled manually by an arrangement of levers. This company has never had any trouble from high-tension oil switches, although they have been used to open some severe short-circuits. On outside lines a disconnecting pole-switch is used. For branch lines a horn-fuse is also used, either on a pole or on a bracket fixture on the outside of the station wall. Small sub-stations are equipped with an air-break fuse inside the station.

automatic release being on the 2000-volt side of the transformers at the generating station. A new line now nearing completion has a construction shown in Fig. 10. The line wire is 0000 B. & S. seven-strand copper, and the operating voltage is to be 60,000 volts. Spans are from 400 to 450 ft. on the straight way. This is a radical departure from the present lines on Puget Sound, but represents the most recent practice in transmission. The old line is to be changed to 60,000 volts and the two lines will then be operated in multiple, with automatic oil switches on each line actuated by overload and reverse-current relays.

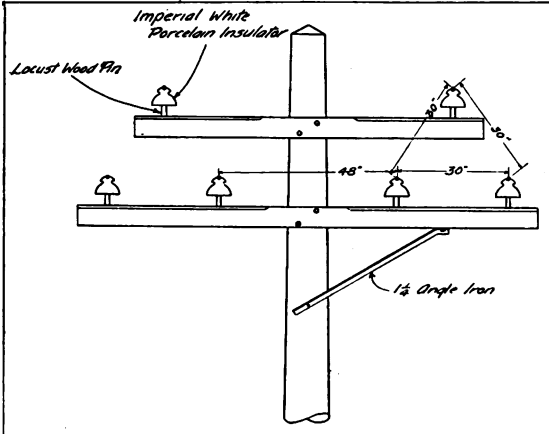

FIG 4

POLE TOP CONSTRUCTION
USED ON FIRST LINES BUILT ON THE
SNOQUALMIE FALLS
SYSTEM

30000 VOLTS, 3φ, TWO CIRCUITS

Seattle Municipal Power Plant. At present this system consists of one 30,000-volt transmission line connecting the generating station on Cedar River with the sub-station in Seattle. This line is of the same construction as that in Fig. 6, except that a three-petticoat, two-piece, 45,000-volt insulator is used. The pins are of eucalyptus wood boiled in oil; the wire is No. 2 solid copper with a 7-ft. spacing. This line was built in 1904, and has given virtually no trouble from electrical failures of insulators or burning of pins. It is controlled by air-break disconnecting switches on the high-tension side, an

Several months ago an attempt was made to operate the old line at 55,000 volts, the transformers being changed from delta to star connection. No difficulty was experienced in dry weather, but in wet weather so much trouble ensued that it was necessary to change back to the old voltage. The high voltage gave trouble by heavy leakage currents setting fire to the wooden pins. No trouble was experienced from electrical failure of the insulators during this time; there should have been no trouble, as the manufacturer's test on this type of insulator is 100,000 volts.

Whatcom County Railway and Light

Company. Nooksack Falls System. This company has a hydroelectric generating station at Nooksack Falls, and supplies power to the city of Bellingham over a single transmission line. This line is built for 60,000 volts, but at present it is operated at 22,000 volts from delta-connected transformers. The length of line is 40 miles; the wire is 0 B. & S. seven-strand aluminum; the spans are about 150 ft. on the straightaway portion, while those at river crossings are as long as 750 ft. The pole-top construction is shown in Fig. 1, except that a pipe pin is used, doing away with the pole-top fixture. From the sub-station in Bellingham a branch line extends about 2 miles to Fairhaven, where there is a second sub-station supplying light and power to that section of the city. This branch line is connected to the main line by pole disconnecting switches. It is of the same construction as the main line with the exception of the spacing between wires, which is 5 ft. instead of 6 ft.

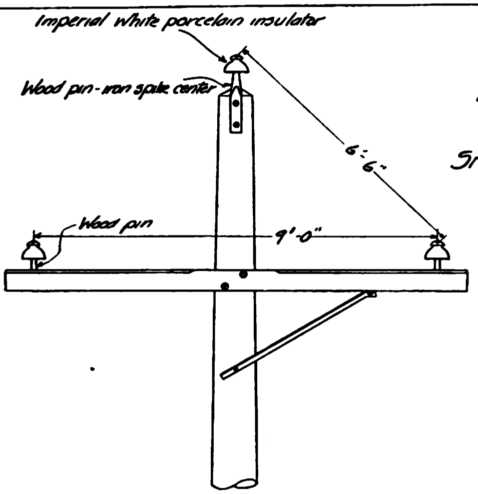
Imperial white porcelain insulator
Wood pin - iron spike center
Wood pin
9'-0"
6'-6"

FIG 5.
RECONSTRUCTED POLE TOP
ON THE
SNOQUALMIE FALLS SYSTEM
30000 VOLTS, 3φ.

The only high-tension switch used on this system is a simple knife disconnecting switch. All switching under load is done on the 2000-volt side of the station transformers. Line short-circuits open the automatic circuit-breakers on the 2000-volt side at the generating station, so that to obtain uninterrupted service it would be necessary to keep the steam generating station in Bellingham on the system at all times. This station is used only in emergency at present, as very little line trouble is experienced.

Having given some of the characteristic features of representative systems in this locality, a comparative discussion may now be of value. In this I shall draw freely on the experiences of the different companies, the opinions of their engineers, and also on the opinions of representative engineers of the present day as set forth in recent papers before the American Institute of Electrical Engineers.

One of the things for which Western practice is criticized is the tendency to build lines that are cheap. Mr. F. G. Baum has said in a paper before the Institute*:

> It may not be as difficult to determine the proper power station and line to build when unlimited capital and ideal power conditions exist as when there is restricted capital, limited revenue, and low-priced power at the consumer's end.

Mr. Baum's idea is the answer to

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*Trans. A.I.E.E., 1907, Vol. XXVI, Part II, page 1555.

such criticism. In the Northwest especially, the lines are very long, passing through rough country; the cost of the transmission system is a big item in the total cost; the power business is usually more or less scattered; and the revenue comparatively small. Economy must therefore be given consideration by the engineer or his designs will not be feasible, and his enterprise will not receive financial support. It requires much more thought and engineering ability to design a satisfactory line with limited expenditure than it does where the line forms a small part of the total investment and its first cost is comparatively unimportant. In consideration of these facts, the item of first cost will be given attention in the following discussion.

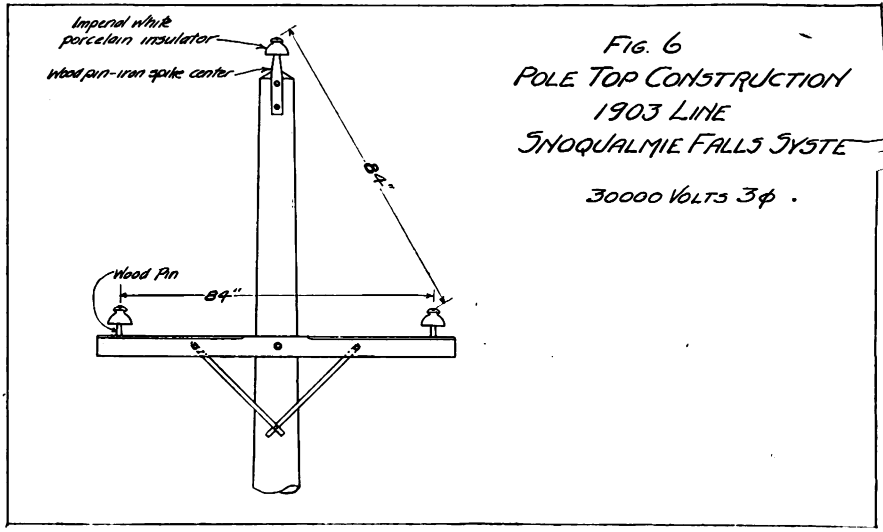
Imperial white porcelain insulator
Wood pin-iron spike center
84"
Wood Pin
84"

FIG. 6
POLE TOP CONSTRUCTION
1903 LINE
SNOQUALMIE FALLS SYSTE
30000 VOLTS 3φ.

Line wire. Opinion seems divided between aluminum and copper for use in transmission at high voltages, but in general it may be said that both are satisfactory. As examples for comparison, take 0000 stranded aluminum and 00 hard-drawn solid copper. The stresses at elastic limit are taken at 15,000 and 20,000 lb. per square inch for copper and aluminum.

	0000 aluminum	00 copper
Resistance, ohms per 1000 ft	0.079	0.0787
Elastic limit, pounds tension	2500	2090
Weight, pounds per 1000 ft.	195	403
Relative cost.............	90	100
Diameter over all, in inches.	0.53	0.3648

There are many practical drawbacks to the use of aluminum; it is difficult to make good joints, as the metal will not take solder; it is a highly electro-positive metal, and when exposed to the air in contact with other metals an electrolytic action is set up in which the moisture of the air and chemical impurities forms the electrolyte. These difficulties may be overcome by carefully made and protected joints. Aluminum has a very high coefficient of expansion with change of temperature, which is apt to be troublesome in climates having extremes of temperature. Its large diameter makes a larger surface for collection of sleet and ice and a larger resisting surface to high winds. In the Puget Sound country extreme temperatures, sleet, and very high winds are never encountered, so that aluminum is well adapted to local conditions.

The systems using it have never had any difficulty which could be charged against the metal. As seen from the above figures, it is somewhat stronger, weighs about half as much, and costs ten per cent less for copper wires of the same conductivity. Ten per cent in the line wire is a fair-size item in the line cost, and additional saving can be effected in freight and teaming in the delivery and stringing up in a rough country.

Poles and construction features. The question of poles versus towers is not considered in this part of the country, where excellent poles are obtainable on the ground and steel is expensive, although it may come in for consideration in later years. When the first lines were built in the Northwest about 10 years ago, the use of 35-ft. poles with 7-in. or 8-in. tops was considered good practice, as the spans were from 110 to 125 ft. and the wires light. Much heavier wires and insulators are now used and the spans are longer, so that the tendency is to increase the size of the poles. The new line now under construction by the municipal light and power plant in Seattle is using 55-ft. poles with 11-in. tops, on spans of 440 ft. On the Nooksack Falls line, 45-ft. poles with 9-in. tops on spans of 150 or 200 ft. are used, which is about the same as on the 1904 lines of the Seattle-Tacoma Power Company and the city plant. It is thus apparent that the trend is toward longer spans, with fewer and more substantial supports.

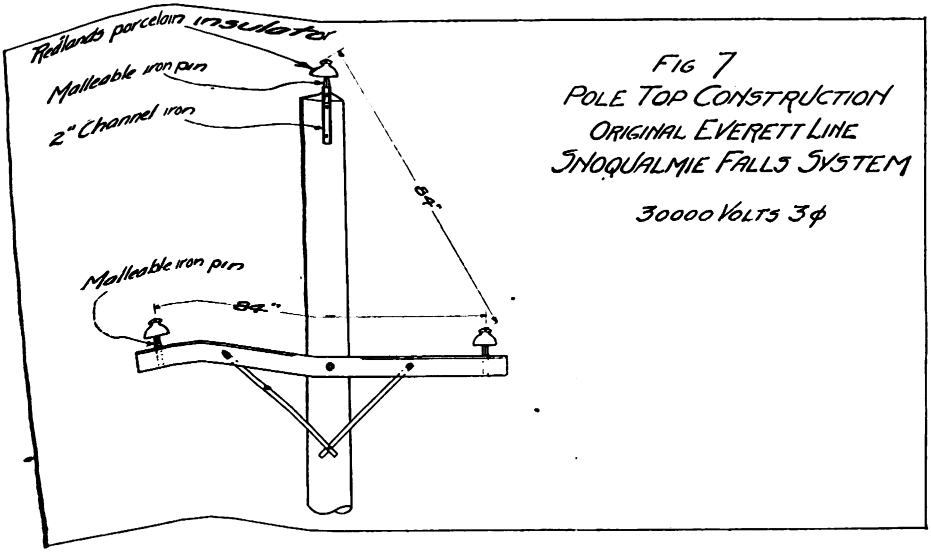

FIG 7
POLE TOP CONSTRUCTION
ORIGINAL EVERETT LINE
SNOQUALMIE FALLS SYSTEM
30000 VOLTS 3φ

The construction details of the pole-top vary considerably in the different systems. In some installations in Utah and Montana the pole-top pin is driven into a hole bored into the top of the pole. In the wet climate of the Northwest this construction would be apt to cause rotting of the core of the pole at the top, so that the pole-top is always pointed to shed the water and the pin fastened to the side of the pole. The experience on every system using wood pins has been that after a number of years the pins are apt to soften or burn. The leakage of currents over the insulator to the pin forms nitric acid from the nitrogen in the air and the hydrogen and oxygen in the moisture, and the acid eats into the pin until the latter becomes quite pulpy. Wooden pins are usually carefully dried and boiled in paraffin or linseed oil, but even then they will begin to soften and burn in from 5 to 10 years, depending on the line voltage. The Seattle municipal plant had a great deal of trouble a few months ago from charring and burning of wooden pins at the point of contact with the insulators, during the time that they were running 55,000 volts on their 45,000-volt line. In this case the leakage currents were so heavy that a high temperature was produced at the threads of the pin, due to the ohmic resistance to the passage of the current at this point. At the lower part of the pin and on the cross-arm there was not so much burning, due probably to the accumulation of dirt and organic matter, and to the fact that the large wet surface offered a lower resistance.

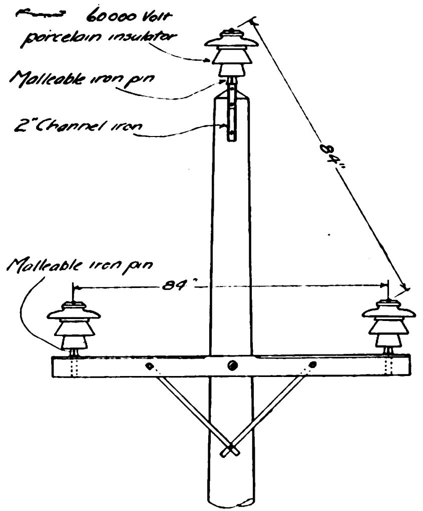

FIG 8
POLE TOP CONSTRUCTION
RECONSTRUCTED EVERETT LINE
SNOQUALMIE FALLS SYSTEM
60000 Volts, 3φ.

Iron pins give entire freedom from such troubles, and also provide the strength necessary for long spans and heavy wires. There are several types of iron pins now in use. The simplest is what is known as the pipe pin, consisting usually of a short length of 2-in. extra-heavy wrought-iron pipe swaged down at one end and cemented in the insulator. Another type consists of a cast-iron cone with a steel bolt up through the centre and screwing into a nipple which is cemented in the insulator. This type is used on the new city line. A third type consists of one solid malleable-iron casting with tapering cross-ribs above the cross-arm and a round pipe shank or a bolt extending through the cross-arm. This is held down by a through bolt or a bolt underneath the cross-arm, and may be threaded and screwed into the insulator. The Northern Colorado Power Company has a pin of this type held down by a U-bolt extending around the outside of the arm. These are the three general types of iron pins now in use in the Northwest. The pipe pin costs from 55 to 60 cents, the bolted cone pin about 50 cents, and the malleable cast-iron pin from 20 to 40 cents depending on the design. The pipe pin has the great advantage of simplicity and absence of bolted parts, and requires no pole-top fixture; but on the other hand it requires at least a 2.5 in. hole in the cross-arm, which necessitates a larger arm. As the insulator must be cemented on the pin, it is necessary to change the pin as well whenever an insulator is broken. With the bolted cone pin only a ⅝-in. hole in the cross-arm is necessary, and as only the small nipple is cemented in the insulator it is not necessary to change the pin when renewing an insulator. Some sort of casting or fixture is necessary at the pole-top in order to use this type of pin, and the cost of this brings the cost up as high as the pipe pin. The malleable cast-iron pin is simply of one piece, and with a threaded head it need not be changed in renewing insulators. If properly designed it is as strong as the other types and is very much cheaper. By a little change in design it may be bolted directly to the pole-top. In general, the practice is to design the pin so that it will bend over before the elastic limit of the wire is reached, so that in case of an unbalanced strain in the line the pin will bend and prevent elongation of the wire. The extreme rigidness of the bolted cone pin may in such a case prove to be a disadvantage.

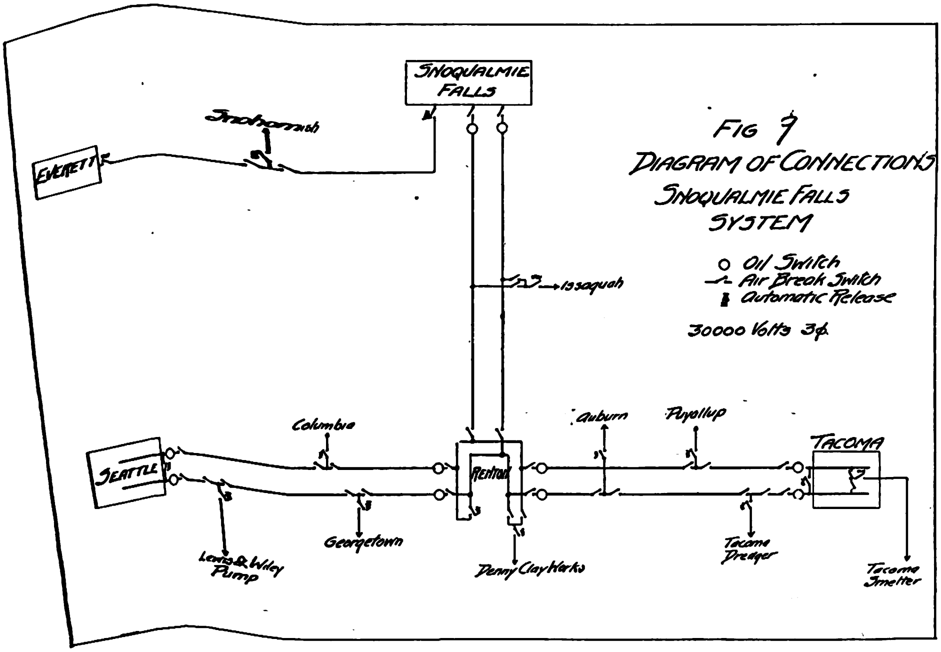
Snoqualmie Falls
Snohomish
Everett
Issaquah
O Oil Switch
Air Break Switch
Automatic Release
30000 Volts 3φ
Columbia
Auburn
Puyallup
Tacoma
Seattle
Renton
Georgetown
Lewis & Wiley Pump
Penny Clay Works
Tacoma Dredger
Tacoma Smelter

Fig 7
Diagram of Connections
Snoqualmie Falls
System

Cross-arms are invariably of straight well-seasoned fir, and should be painted or given a coat of preservative. Their cross-section varies from 4 in. by 6 in. in short spans to 6 in. by 8 in. with long spans and heavy wires.

The insulators used are usually of a standard type and made of porcelain. The city line has a few glass insulators, but while these are electrically satisfactory they are very easily broken and are rarely used. Experience proves that it is advisable to test all high-voltage insulators before accepting them, especially for line work for over 30,000 volts. The cost of this test should not exceed 5 cents per insulator. The test voltage should be made at least double the line voltage. The insulators are set head down in a trough of water deep enough to cover the wire groove, and sufficient water poured in the pin hole to cover the threads. A metal rod is then put into the pin holes and the test voltage applied between this rod and the water in the trough. Where the insulator is made of several shells cemented together, each shell should be tested separately for its share of the voltage. It is of extreme importance that the porcelain in high-tension insulators be of good quality and free from cracks or pits. On the Snoqualmie system two different insulators of almost exactly the same shape are used—white imperial porcelain on the main lines and chocolate colored porcelain insulators on the Everett line, The porcelain in the latter was not quite so good as used in the white insulators, and they would not hold up under so high a voltage, even though they were of the same design. The fracture of high-grade porcelain shows a vitreous and almost polished surface. The glaze possesses no insulating value, but is simply to prevent the adherence of dust and dirt, and hence it should cover the entire outer surface. High-tension porcelain should be thoroughly vitrified and non-absorbent. A test for porosity is obtained by soaking the porcelain in ink; if non-absorbent the ink should be easily washed off with water.

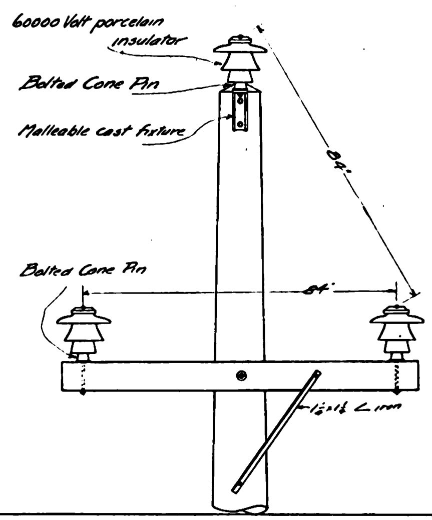

FIG. 10
POLE TOP CONSTRUCTION
SEATTLE MUNICIPAL LIGHTING SYSTEM
NEW LINE
60000 Volts, 3 φ

Spans. The subject of spans in transmission lines has been given considerable attention by engineers in the last few years. During the early days of high-voltage work short spans were thought necessary in order to insure against breakage of wires, and as the wires were usually small and the spacing between them not over a few feet, long spans would have given trouble. It has been found, however, that wires never break of their own accord if properly strung and if all kinks are replaced by splices, and that if a spacing of 6 or 7 ft. is used there is no danger of the wires swinging together. Large wire having great tensile strength is now used and long spans are operated with safety. The weak point in a transmission line is its point of support, and anything which reduces the number of supports decreases the number of weak points and also the loss from leakage. The great advantage lies in the reduced cost. This reduction in cost, however, will not hold if the length of span is made too great, as it then becomes necessary to build expensive towers and heavy construction in order to take the strain safely. In order to determine the most economical length of span, the procedure outlined by D. R. Scholes* is the simplest and may be applied to wood poles as well as to steel towers. A curve is plotted with cost per mile and length of spans as coördinates. As an example let us assume a 55,000-volt line. With spans of 100 to 150 ft., a 5-ft. spacing between wires is good practice. A light, malleable cast-iron pin, 4-in. by 6-in. cross-arms, and 40-ft. poles with 8-in. tops would be used. The labor of setting and framing the pole will vary considerably with the locality, but may be estimated at $6.00. We then have the cost per pole:

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* Transactions A. I. E. E., 1907, vol. XXVI, part II, page 1221.

3 insulators and pins @ $1.80	$5.40
1 cross-arm, braces, and bolts	0.75
1 40-ft. pole @ 0.10	4.00
Labor	6.00
	$16.15

With 35 poles per mile (150-ft. spans) this comes to $565.25 per mile, and with 45 poles (118-ft. spans) $726.75 per mile. For spans of 250 to 500 ft. a heavier construction is needed, with a spacing of at least 7 ft., between wires, similar to the new line of the municipal plant in Seattle. At least 50-ft. poles with 10 in. tops are needed, with 5 in. by 7-in. cross-arms. A substantial design of pin is needed, well fastened to the cross-arms. Taking a design similar to that on the city line:

3 insulators and pins @ $2.20	$6.60
1 cross-arm, with braces and bolts	1.20
Pole-top fixture	0.20
1 50-ft. pole @ $0.13	6.50
Labor	6.50
	$21.00

With 20 poles per mile (260-ft. spans) the cost will be $420.00 per mile, and with 15 poles (350-ft. spans) $315.00 per mile. This construction if carefully designed can be used up to 500 or 600 ft. Although single poles are used for spans up to 900 ft. in California, the opinion here seems to be that with spans over 700 ft. an A-frame should be used with double construction. The cost of this may be estimated at:

6 insulators and pins @ $2.20	$13.20
2 cross-arms, braces, and bolts, etc	3.00
2 60-ft. poles	15.00
Labor	11.00
	$42.20

With 6 poles to the mile (860 ft. spans) the cost will be $253.20. If the line has many bad curves this figure will be considerably increased. With spans over 1000 ft., a 4-pole tower is recommended. This will cost:

12 insulators and pins	$26.40
Timbers and framing	9.00
4 60-ft. poles	30.00
Labor	25.00
	$90.40

With 1200-ft. spans the cost will run up to $400.00 per mile, which is past the economical point, as seen on the curve in Fig. 11. These figures are only approximate, and are given chiefly to illustrate the principle involved. The influence of curves, character of country, etc., may make long spans impossible in some parts of the line, which will make the most economical span shorter. On the other hand, a mountainous country affords excellent opportunity for spans from hill-top to hill-top, making a large saving in clearing trees on the right-of-way, etc. Each particular line must be worked out with reference to the local conditions.

Switching and operation. Some diversity of opinion exists as to the best scheme of switching. The Electron system with two 0000 copper lines and 55,000 volts uses automatic circuit-breakers at each end of its transmission lines, and normally these lines are not connected in multiple on the high-tension side. A short-circuit on the system which lasts only a few seconds will not open the breakers, as the latter are protected by relays; but a short-circuit which holds on will open the line at Electron and also at the sub-station in order to prevent feeding back into the short-circuited lines. The Snoqualmie system with two 0000 aluminum lines at 30,000 volts has no automatic release on its high-tension lines, except where small sub-stations or branch lines tap the main system, and on the switches used for connecting the lines in multiple. A short-circuit coming on either line usually releases the multipling switches. The operator at the falls can then usually see from the line ammeters which line the short-circuit is on, and opens that line with the oil-switch. If for any reason it is not apparent which line is in trouble, the voltage is lowered and the short circuit is "pulled" until it is burned off, but both lines are never cut out. Automatic circuit-breakers are used between the steam generating station in Seattle and the transmission system so that the steam plant will not feed back into the short-circuited high-tension line. This non-automatic method of operation has given excellent results on this system, as most of the line short-circuits can be burned off within one or two minutes at the most, and the only effect at the sub-stations is a bad dip in the voltage. This is much better than shutting down for the five or ten minutes necessary to switch out the bad line, as all synchronous apparatus is then thrown out and must be started up and synchronized all over again. Long lines with comparatively small wires are more easily handled in this way. With a short line, high voltage, and very heavy copper a surge may occur with a bad short-circuit which will have a destructive effect on the windings of the generators unless their impedance is high. This country is rapidly developing, and within a few years much heavier capacity lines and higher voltages will be employed, and a more complex system with a number of stations tied together will result. More or less automatic apparatus will then become necessary. The plans of the new Seattle municipal system shows the best practice for automatic line protection. They expect to use both overload and reverse-current relays in connection with automatic circuit-breakers. Unless they are well made, and judgment and care used in their installation and use, the relays may not give satis-

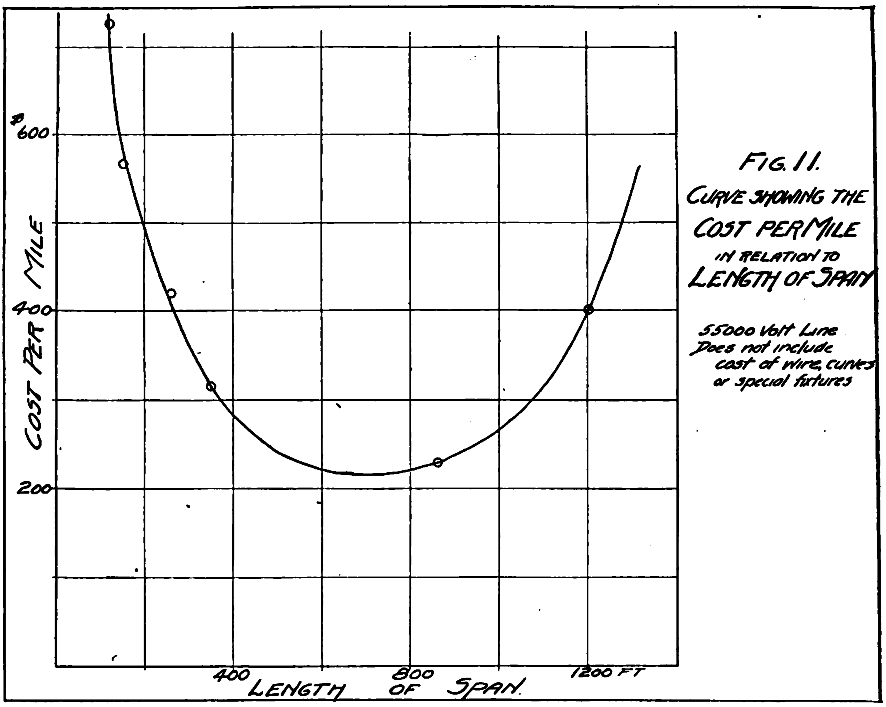

FIG. 11. CURVE SHOWING THE COST PER MILE IN RELATION TO LENGTH OF SPAN

55000 Volt Line
Does not include cost of wire, curves or special fixtures

faction. The primary object of the relay is to control the automatic release of the circuit-breakers. The ordinary overload relay may be set for a certain time limit, and if the overload continues for that time the relay will trip the breaker. If a heavy short-circuit comes on the line when there are only a few generators in service, the voltage may be pulled down too low to operate the relay, and the design must be such as to insure operation at very low voltages and power-factors. Reverse-current relays are used at the sub-station end of the line to prevent feeding power back into the defective line where two lines are operated in multiple. Relays should open the short-circuited line at each end quickly enough to prevent synchronous apparatus on the system from falling out of step; but at the same time they should not operate at slight surges caused by an operator making a slight miss in synchronizing. During the synchronizing of generators at Electron, it is the practice to cut out the relay on the generator circuit-breaker so that a bad throw will trip out the incoming machine instantly without disturbing the system. The general conclusion to be drawn from switching practice in the Northwest is that non-automatic operation is satisfactory, and will give good results on systems where the line conductors are not too large and the voltage not over 50,000 volts. In very large and complex systems handling large amounts of power at short distances, automatic protection becomes necessary.

Annual Convention, A. I. E. E. Thousand Islands, N. Y., June 28, 1909.

At the meeting held February 19, 1909, the Board of Directors voted to hold the next annual convention at the Hotel Frontenac, Thousand Islands, Frontenac, New York. The convention will begin Monday, June 28, 1909, and will end at a time to be announced later. A tentative announcement of the convention program will be made in the April PROCEEDINGS.

Pioneer Developments Within the General Electric Company*

I have been asked to speak to the Section members to-night regarding "Pioneer Developments within the General Electric Company." I have attempted many different lines of work since the beginning of my business career, some 28 years ago, but this is the first time I have tried to fill the post of historian. Dr. Steinmetz has said that he always likes to play the rôle of a prophet, because to be a successful prophet it is only necessary to put the date of your prophesies far enough in the future to insure that all your present listeners will be dead. I suppose that I would find the historian's job equally easy if I were sure that there were no living witnesses of the times and events which I am asked to describe, to bob up and question my story. However, I will try to be reasonably exact and not draw too much upon my imagination, and at the same time I hope to stop my story long before reaching modern events likely to be within memory of the majority of those present.

As you are aware, the General Electric Company was formed as a consolidation of the Thomson-Houston and Edison General Electric companies. Each of these two companies had grown from the consolidation of a number of other smaller companies, the leading company being the Thomson-Houston Company on one side, and on the other the Edison General Electric Company, a consolidation of the numerous companies formed as a result of Mr. Edison's activities. My knowledge of the history of the struggles in pioneer work of the Edison group of companies is naturally no greater than that of any other interested worker in the same field. I will, therefore, not take your time to give you second-hand information, but hope you will have an opportunity to obtain this story from some of the workers who were personally associated with Mr. Edison in the early days.

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* A paper read by Dr. E. W. Rice, Jr., before the Schenectady Section of the American Institute of Electrical Engineers, October 29, 1908.

My connection with electrical work professionally dates back to July, 1880, when the American Electric Company was formed to manufacture the electrical inventions of Professors Elihu Thomson and Edwin J. Houston, of Philadelphia. The American Electric Company was located at New Britain, Conn.

I was a pupil of Professors Thomson and Houston at the Central High School in Philadelphia, and as a student was especially interested in scientific work. Professor Thomson was a particularly brilliant teacher, and even at that early date was willing to devote any amount of time to answer the questions of his students. I think that probably I attracted attention because I asked more questions than some of the rest. In any event, shortly after Professor Thomson organized his company at New Britain, he offered me a position with him which I gladly accepted. At that time there was but a small group of workers in the electrical field, the most prominent of which were Charles F. Brush, Edward Weston, Thomas A. Edison, Wm. Hochausen, and Hiram Maxim. Edison had just announced his invention of the subdivision of electric light; in other words, the incandescent lamp. While his announcement had the effect of producing. a panic among the gas companies both in this country and abroad, it was not regarded among the class of electricians I have mentioned as a serious competitor. The efficiency of the lamp, which consumed 4 or 5 watts per candle, as compared with 0.5 watt per candle for the arc lamp, was so low that it seemed to those who had taken up the exploitation of the arc light that the incandescent lamp system was too inefficient to compete commercially with the superior arc lamp. In addition to this, I remember that Mr. Edison's proposition to distribute a large number of such lamps at the low pressure of 100 volts called for such a large amount of copper that it seemed impossible that any extensive application could be economically made. I mention this merely to show the point of view of Edison's rivals at that date.

I am glad to say that the development of the electrical art has demonstrated the breadth and soundness of Edison's early work. In the early days the output of the different companies was exploited as a system under the name of the inventor; for example, the Edison System, Weston System, Brush System, Thomson-Houston System, Maxim System, etc. Adopting this phraseology, I would state that all the systems excepting the Edison System consisted of an arc dynamo and arc lamps operated in series. They were divided into two classes known as the "long arc" and the "short arc." Brush was the exponent of the long arc system. He was one of the earliest and most successful inventors in the arc-light field. At the date I mention, 1880, he had already succeeded in producing an arc dynamo capable of operating 16 arc lamps on one circuit. These arc lamps were of the so-called long arc type; that is, the lamp consumed about 45 volts with a current of about 10 amperes, or as it was called in those days, 10 "webers." These machines were selling quite rapidly and the business of the Brush company was most prosperous.

The machines were well constructed mechanically and electrically, considering the state of the electrical art at that time. The arc lamps had what was known as the "differential" type of magnet for feeding the carbon. It is difficult at this date to understand the situation. It may help you to appreciate it, however, to say that the Brush patents purported to cover, and were actually believed to cover, any form of differential control for feeding the carbons. They also controlled any form of cut-out operated by the shunt circuit. His dynamo was of the so-called "open coil" type, with which you are familiar. It was thought to be more efficient than the "closed coil" type represented by the Gramme ring and the Siemens or drum-type of winding. The Brush patents were supposed to cover any form of dynamo of the open-coil type.

Weston was exploiting a type of machine similar to the Siemens armature and Siemens winding; that is, the closed-coil type, exactly similar to the Siemens winding which is now so familiar. He advocated the so-called short arc which was operated with a current of 18 to 20 amperes with about 30 volts across the terminals of the arc. This so-called short arc was really not an arc in the modern sense at all, the carbons being separated only about 1/64 in. to $\frac{1}{32}$ in. It gave a fairly steady light somewhat yellow in quality, but inefficient as compared with the so-called long arc. Of course, the terms long arc and short arc were really trade names, and purely relative. The long arc was merely the usual arc, such as one obtains by separating the carbons in the open air to a point where the hissing ceases. With a current of 10 amperes this point is reached with a separation of about $\frac{1}{16}$ in. to $\frac{1}{8}$ in. Of course all this happened long before the days of the enclosed arc or flame or luminous lamps, which may be truly said to have long arcs.

The Brush machine may be considered as a prototype of the modern two-phase machine, whereas the Thomson-Houston machine was the original three-phase machine. Each of these machines was provided with a commutator. As you are aware, Professor Thomson found that he could, in a three-coil machine, connect together three of the ends and commutate the remaining three. He called this connection the "common connection", the identical connection that would now be known as the star connection. If each of the wires leading to the three segments of the commutator were connected instead to three collector rings, the arrangement would be that now so commonly used in a three-phase generator.

Professor Thomson invented many forms of arc lamps, but the type which was finally selected and sold in those early days was the "differential", but one in which the series and shunt windings were placed on separate magnets and actuated armatures on opposite ends of a walking beam in distinction from Brush's method of placing the series and shunt windings on the same magnet and depending upon neutralization of the series winding by the shunt.

The Thomson-Houston system consisted not only of a dynamo and arc lamps of novel construction, but had in addition the entirely new and extremely important feature of an automatic regulator which was designed automatically to maintain constancy of current in a series circuit, no matter how many lights were in operation. This constituted a most important, radical, and valuable improvement, patents for which were obtained and generally respected for a number of years. It is difficult for me to give a proper conception of the importance of this automatic regulator feature. You may realize its importance when I tell you that the Weston and Brush machines were so constructed that in case one or two arc lamps were extinguished in a circuit of, say, 12 to 16 lamps, the current would increase and the burning of the lamps would be most irregular and unsatisfactory. In practice it was necessary for the users of the Weston and Brush machines to keep a number of arc lamps near the dynamo, which could be cut-in in case any of the arc lamps on the outside circuit were extinguished for any cause. I have myself seen large numbers of arc lamps operating in this manner in the early central stations of the Brush and Weston systems. It can readily be understood that this lack of a self-regulating feature involved a great waste of power, useless waste of carbons, and a large amount of additional attendance. I think that the regulator constituted one of the most important advantages of the Thomson-Houston system. It insured uniformity of light, minimum attention, and increased efficiency. It made the machine and system more reliable and " fool proof." The first machine built at New Britain in the latter part of 1880 was, as I remember, capable of operating 4 arc lamps, these lamps consuming about 45 volts and 10 amperes each. The next size operated 10 lamps, and this was quickly followed by one designed for about 16 to 20 lamps.

The attempt to produce a machine with only one commutator containing but three segments, which would operate from 16 to 20 arc lamps, was not at first crowned with success. The Brush machine operated with considerable success with 16 lamps. The connections of this machine, however, were such that the voltage on the commutators was limited, and it had two commutators connected in series so that it was really equivalent to two 8-lamp machines. Professor Thomson could, of course, have adopted the same expedient and wound his armature with two sets of three coils, each set connected to a commutator and connected these two commutators in series. Such a machine was actually constructed and operated satisfactorily, but it did not please Professor Thomson as it considerably complicated the automatic regulator feature.

I would say in passing that the Thomson automatic regulator was one in which the brushes on the commutator were moved by a motor magnet, and although this method was extremely practicable and simple when applied to one commutator, it became rather complicated when extended to two commutators. The particular difficulty which we met was the " flashing-over " or short-circuiting of the commutator at irregular intervals, this flashing over being practically absent with a single commutator operating about 10 to 12 arc lamps but quite troublesome with 16 to 20 arc lamps. Professor Thomson was determined, if possible, to maintain the almost ideal simplicity of his machine. He made many experiments which would take too much time to describe, to ascertain the cause of the flashing-over, and the remedy. I would mention that he tried the use of condensers, many forms of commutation with increased insulating distances, etc., but finally in a moment of inspiration, such as came to him on many occasions when great difficulties were to be solved, he thought of inserting a cool stream of air at reasonably high pressure between the brush and the leaving segment. He reasoned that if an air-film or stream could be maintained, flashing-over would be rendered most difficult. I well remember that in his haste to try the experiment he took a piece of brass and fashioned it in the form of an elongated nozzle and used it to blow on the commutator. It was found that as soon as he blew on the commutator the flashing would not occur. He then made another nozzle and I blew on one brush while he blew on the other; and as long as we could keep blowing, the machine would run without flashing, and this under conditions which were otherwise inoperative. It did not take Professor Thomson long to design a little self-contained blower which fed the air to the commutator through appropriate nozzles. It was found when this blower was placed on the machine, that instead of the limit of commutation per commutator being some 8 to 10 lamps, as heretofore explained, it was possible to run the particular machine up to 20 lamps on a single commutator without any signs of flashing. I would mention that even a 10-lamp machine without the air-blast could be made to operate without occasional flashing only by very careful manipulation. The commutator required slight lubrication in order to prevent undue cutting of the brushes, and if this lubrication were overdone, as was sure to be the case with careless operators, or the commutators allowed to get dirty or the brushes badly worn, the machine, even with 8 to 10 lamps, without the air-blast was liable to flash in such a way as to render the lighting unsatisfactory and disagreeable. The air-blast, however, cured all this, and it was eventually found entirely practicable to operate machines with a single commutator with as many as 50 to 60 arc lamps, and such a commutator could be covered with dirty oil without in any way affecting this operation.

I have taken your time to explain somewhat in detail the invention of the air blast as applied to an arc-light commutator, because I consider that it exemplifies the character of the difficulties met by Professor Thomson in his early work, and his original, practical, and simple methods of solving such difficulties. I believe that the commercial success of the company was due as much to this characteristic of Professor Thomson's work as to any other cause. Professor Thomson loved simplicity, and it was fortunate that he did, because in those early days a complex and unreliable piece of apparatus stood little chance of surviving.

It may help you to form some conception of the conditions surrounding the early workers at the time of which I am speaking; namely, about 1881 and 1882, if I describe the general conditions in regard to electrical measuring instruments, material available for manufacturing, etc. At that time the volt and the ohm were, as I remember, the only electrical units established and in use. The Paris Congress which met in September, 1881 adopted the C. G. S. system which had been previously put forward by the British Association. This same Paris Congress confirmed the names and application of "volt" and "ohm." They gave the name of "ampere" to the unit of current which had been previously known as the "veber" or "weber." They also recommended the use of the terms "coulomb" and "farad." The term "watt" had not yet been introduced.

The ampere meter was not generally made until some time in 1882 or 1883. However, Professor Thomson recognized the importance of adopting a scientific standard and of maintaining this standard, and therefore constructed an instrument on the lines of the Deprez galvanometer. This consisted, briefly, of a coil of wire through which the current to be measured was passed, which coil was so arranged as to deflect a thin soft iron needle placed between the poles of a powerful permanent magnet. The magnet served the purpose of holding the needle in place and limiting its oscillation. This instrument was called the "herring-bone" galvanometer, and was set up in our testing room at New Britain, and the deflection which was given by the current which we used on our machines was marked on a dial. Considerable time was spent in carefully calibrating this current by the silver and copper voltameter method. As a matter of fact, this current was then called 9.6 webers, or what would now be called 9.6 amperes. This old galvanometer was in use for many years and was calibrated from time to time and found to maintain its accuracy to an extraordinary degree. Every machine that was tested was adjusted by it. Incidentally, I may say that this galvanometer was so arranged that the scale was of the horizontal edgewise type, and its magnet upon which the permanency of the calibration depended was hardened by Professor Thomson.

Our first standard of resistance was a 10-ohm coil which Professor Thomson brought from the Central High School, of Philadelphia, and which was a copy made by himself of a resistance coil in a resistance box belonging to the physical laboratory of the high school, made by Elliot Bros., of London, who at that time were the recognized manufacturers of such standards. Using this standard 10-ohm coil as a basis, other coils, 1, 2, 3, 5 ohms, etc., were made and used as a

Wheatstone bridge for measuring resistances. The necessary astatic galvanometer was made by Professor Thomson with such assistance as I could render. Professor Thomson also made a sliding-scale Wheatstone bridge of the wire type. These instruments were used to make the necessary measurements of the armature coils, field coils, arc lamp magnet coils, etc. Most of the measurements during the first two or three years were made by myself, personally.

The insulating materials which were used in the construction of dynamos and arc lamps were at first canvas soaked in paraffine, and red paper, similar to that which is still used, shellaced to keep out moisture. We soon found that this material was not sufficient, and for the larger machines adopted a composite insulation made of shellaced mica and red paper which was a prototype of the present composite mica insulation. Of course the copper wire was purchased from the wire makers covered with cotton thread as at the present time. It was not, however, of such uniform quality, and double-cotton-covered wire was not common for several years.

Our transmission circuits up to 1882 were bare copper wire of either 6 or 4 B. & S. It was customary to fasten these copper wires to partitions and rafters by means of ordinary iron staples. I well remember that it was considered quite an advance when porcelain insulators were employed, and a real extravagance when covered wire was first suggested for interior circuits. This suggestion, in fact, first came from the Underwriters of the Mutual Fire Insurance Companies of New England, and was presented to us by Mr. C. J. H. Woodbury upon a visit which he made to New Britain sometime in 1882. In fact, the name " underwriters wire " was given to this product. It was a long time before covered wire was adopted for outdoor use. The only insulator known for outdoor use was the common glass telegraph insulator, and this was generally employed.

We were greatly hampered by the inability to obtain long lengths of cotton-covered copper wire. For a long time the maximum weight which we could obtain in one piece was 16 lb. This necessitated making quite a number of joints in field coils of even moderate size machines. It also called for frequent joints in the armatures. Of course wires of special shape such as flat wire or square wire were absolutely unknown.

There was nothing to be had in the way of porcelain insulating material or special moulded compounds which are so universally employed by the electrical engineer and designer at the present time. Paraffine and shellaced woods were used for many purposes, boxwood being especially valuable. Hard rubber could be had only in the form of sheet and tubes. Carbons were so crooked that we found it necessary to sort all that were purchased and in order to save those that were not too crooked, a method of grinding the end of the carbon which was placed in the holder, so as to minimize the effect of the crook, was employed. A cheap and tough substitute for hard rubber was finally discovered in the shape of leatheroid which was one of the earliest insulators of this type to be employed.

I think it will be clear to you from what I have said that the industry was confined to the manufacture of arc lamps of one size and character; the so-called 2000-c-p. arc lamp consuming 10 amperes and 45 volts at the arc. Arc lamps of small candle-power consuming 6.6 amperes were not introduced until some time in 1884 or 1885.

While it was known that a dynamo electric machine was reversible—that it could be used as a motor when supplied with electricity—no regular commercial application was made of this fact until several years later. However, we did operate our pattern shop for several months in 1880 by a 5-lamp arc dynamo used as a motor. The electricity to operate this motor was furnished by an arc-light series dynamo driven by our main engine. The speed of the motor could be adjusted by shifting the brushes of either the motor or the generator, or both, and also by varying the field strength.

Even in those early days the question of efficiency and guarantees was considered of vital importance, and every attempt was made to obtain the efficiencies of our dynamos with a view to determining the amount of power per standard arc lamp. One of the first and most important instruments erected in our testing room at New Britain was a large transmission dynamometer —large for those days—capable of measuring the power transmitted to our largest machine, one of 16 to 20 lamps capacity. Every machine which was constructed during the first few years was tested on this transmission dynamometer, and the current was kept constant by means of the "herring-bone" galvanometer already mentioned, the arcs were adjusted to a uniform length, and presumably consumed on the average a fairly uniform voltage. Our efficiency tests were probably not greatly in error.

While it was extremely difficult with the meagre measuring devices at our disposal to obtain exact quantitative electrical measurements, there was no lack of appreciation of the necessity for such measurements, or of a desire to obtain them. According to my recollection, much was known in a qualitative manner which was in later years only confirmed by exact quantitative measurements. To illustrate, I may say that Professor Thomson, at least, thoroughly understood in 1880, and possibly earlier, the general principles controling the flow and distribution of magnetism in a magnetic circuit, the approximate relation of the permeability of cast iron and wrought iron, the general shape of the saturation curve, etc. In fact, when Dr. John Hopkinson a few years later wrote his classic paper on the predetermination of the characteristics of the dynamo electric machine, the principles there enunciated were thoroughly appreciated and recognized as familiar. It was well known that the electromotive force in a dynamo was proportionate to the speed, the number of turns, the amount of magnetic flux, etc.

An examination of early designs will show a recognition of the necessity of proper ventilation of the armature, and constants had been worked out as to the surface required for the radiation of heat produced in stationary coils. It was clearly recognized that the iron core of an armature which was subjected to alternating magnetic flux was subject to Foucault or eddy currents, and therefore required subdivision for the purpose of insulating against such eddy currents. The core of the armature of Thomson-Houston machines was made of iron wire wound upon a skeleton support, this skeleton being carefully insulated so as to prevent the circulation of eddy currents.

Weston was probably the first one in this country regularly to employ a laminated sheet-iron armature, the armatures of his arc machines having this construction.

Brush used for a number of years a cast-iron armature which was slit in such a direction as to reduce the eddy currents. Of course this cast-iron armature was subject to heavy hysteresis losses, but the eddy currents were kept down by the high specific resistance of the cast iron. Professor Thomson always considered, however, that the cast-iron armature was the poorest and most inefficient feature of the Brush design, but it had the merit of cheapness. It was eventually replaced by a sheet-iron structure.

Of course in these modern days the fundamental characteristics of a series constant-current dynamo are well understood; that is, it is known that such a machine must have a substantially vertical characteristic—the current must be maintained constant over a wide range of the resistance of the external circuit. For example, a machine that is capable of sending a current of 10 amperes through a resistance of 100 ohms must not send appreciably more than 10 amperes when the resistance of the circuit is reduced to 10 ohms. This can only be accomplished by having the electromotive force vary in proportion to the resistance. This requirement of a constant-current machine was not clearly understood 25 or 30 years ago, excepting by very few. I think that Professor Thomson and Mr. Brush were probably the only men who fully appreciated this requirement. Professor Thomson's machine was designed so that it inherently had a " characteristic curve " which was very nearly vertical, and could be rendered entirely vertical by the action of the automatic regulator already referred to. Brush attempted to obtain the same results by a regulator which shunted his field, and did obtain the required conditions over a limited range. However, not only was it necessary for the machine to have the characteristics I have mentioned in order to enable its load to be changed, but it was necessary in order to operate with stability. Of course if such a machine were to operate through a dead resistance, or through a resistance with a positive coefficient, such as iron wire, copper wire, or other similar circuits, there would be no danger of instability. The electric arc can, however, be considered an unstable electrical resistance, the resistance of the arc itself being an inverse function of the current; that is, the greater the current which flows through the arc the less the resistance. For this reason, an arc cannot be operated across a constant-potential multiple-arc circuit, but requires the interposition in series with it of a resistance having a positive coefficient, in the sense that the electromotive force consumed by the resistance increases with the current rather than diminishes. In the early days arc lights were the only devices placed in the circuit of the dynamo, and constituted from 85 per cent to 90 per cent of the total resistance of the external circuit. It was therefore essential that the machine should have such a characteristic that a decrease in the resistance of the circuit would not cause an increase in the current, or at least would not cause an increase in the electromotive force produced at the terminals of the machine; because if an increase of electromotive force were produced by such a reduction in resistance, the current would increase and lengthen the arcs, and in doing so would increase the resistance so rapidly that the electromotive force would fall, with the result that voltage and current supplied by the machine would go through a series of oscillations. Professor Thomson called this phenomenon " hunting." It was simply an unstable phenomenon which, if uncontrolled, rendered impossible the proper operation of an arc-light circuit.

Professor Thomson recognized that an arc machine needed the characteristic I have mentioned, and the name which he used for it was entirely appropriate. He said the machine should have a " drooping " characteristic or a limited horse power capacity, and he stated that this characteristic could be obtained by a saturation of the magnetic circuit and by having the armature sufficiently powerful with respect to the field; in other words, what we would recognize at the present time as a relatively weak field and overpowering armature reaction. While we now know that this machine should have this characteristic, I repeat that in those days it was not generally so understood, and, as a result, many designers who would like to have produced satisfactory arc light machines failed in their attempts. Also, such machines as the Thomson-Houston and Brush, which did possess this admirable characteristic, were severely criticised, particularly by mathematicians and electrical writers, as being inefficient and unreliable. The early critics overlooked entirely the object for which these machines were designed.

I have now described very imperfectly some of the conditions, difficulties, and achievements of the earliest pioneer days of the company. Most of the work of which I have been speaking was done between 1880 and 1883. I will not take your time to go into a detailed description of the work which followed. I mention merely in the briefest possible manner a few matters of possible interest. In about 1883 or 1884 our circuits had become extended enough to attract the attention of lightning; we had a few arc lamps burn out and we lost a machine under conditions which were known to be due to the static effects of lightning. This greatly disturbed our commercial people, who feared that the machines were so weak that they would be subject to frequent interruption through this cause. Professor Thomson was asked if he could not do something to meet the condition. Of course lightning-arresters consisting of two pieces of brass, one connected to the circuit, and the other to the earth, placed close enough together to allow the spark to earth, had been used on telegraph and telephone circuits. But such a device could not be used on an electric-light circuit, as the dynamic current would follow the spark so produced and short-circuit the system. After considering a number of different methods, all of which involved moving parts, switches, etc., Professor Thomson conceived the beautiful idea of placing a gap in the field of a powerful magnet, either an electromagnet or permanent magnet, and utilizing this field to disrupt the arc produced by the dynamo. I remember after making the sketch and explaining the idea to me, that he took a magnet and tried its effect upon an arc light in the circuit of a machine which we happened to be testing at the time. I think it was a 10-light machine. He showed that it was impossible for the machine to maintain an arc even across a very small gap. He immediately made a lightning-arrester upon this principle. It has been generally used in various forms ever since. He did not rest content in applying this principle to the lightning-arrester, but immediately suggested its application to electrical switches. This idea of the magnetic blowout has been used in hundreds of thousands of switches, particularly in railway controllers. It is difficult to conceive of a solution more elegant and yet more simple.

Professor Thomson has always shown a deep interest in alternating-current phenomena. He often spoke to me about the possibility of employing "induction coils" as he termed them, for the operation of arc or incandescent lamps, recognized fully the advantage of transforming from high to low potential and vice versa; in fact, one of the first machines which Professor Thomson built and operated in Philadelphia, in 1879, was a self-excited alternator from the secondary circuit of which some arc lamps were operated.

About the earliest practical use of alternating current was made by Gaulard & Gibbs, who used a series system which, of course, had certain fundamental objections applying to such a system. Professor Thomson about 1883 invented a method of using such transformers or induction coils in multiple arc, and a broad patent was issued to him. About 1884 to 1885, William Stanley, of Gt. Barrington, and Zippernowsky and Deri, of Buda Pesth, were advocating and introducing a similar system. Stanley was taken up by the Westinghouse Electric and Mfg. Company, and his work formed the foundation for the Westinghouse alternating-current system which was rapidly developed at Pittsburg by Stanley, Shallenberger, and others. The Thomson-Houston Company did not immediately push the alternating-current system, largely for the reason that Professor Thomson considered it dangerous, as he could see no way of preventing an accidental contact between the high- and low-potential circuits, with consequent danger to human life. He believed, therefore, until some positive solution of this difficulty could be reached, that the system should not be recommended. He finally suggested that the secondary system should be positively grounded at the middle point of the transformer. Objection to this was made by the underwriters and other people, as the idea was entirely too radical. He then proposed the introduction of a metallic shield between the primary and secondary circuits, which metallic shield was grounded. This met with the underwriters' views, but improvement in the character of insulation and the general willingness of the public and manufacturers to take some risk were such that for some years the alternating-current transformers were used without the grounded shield or grounded secondary. It is only within comparatively recent times that the objection to the grounded secondary has been finally disposed of and this practice universally recommended.

In about 1885 Professor Thomson made one of his greatest inventions, that of electric welding by means of heavy currents; that is, what may be termed the incandescent method as distinguished from arc welding. His method of welding has been very generally introduced into the mechanical arts, such as, for example, making wire fence, wire hoops, bicycle parts, wheel rims, chains, etc. By this method, any substance may be welded, even substances which before that time were supposed to be non-weldable, such as copper, brass, zinc, and, of course, iron, steel, etc.

While engaged upon alternating-current work, particularly transformers designed for electric welding, Professor Thomson discovered the phenomenon of alternating-current repulsion. This was vigorously followed up by experimental work, and led to the invention of the so-called "repulsion" motor and other alternating-current motor devices. The phenomenon was quickly recognized by Professor Thomson as being due to the action of out-of-phase currents, and he continued his experimental development until he produced several motors capable of satisfactory operation from single-phase circuits. About this time, however, the production of a satisfactory recording wattmeter for the metering of electrical circuits took up his time, and the repulsion motor work was temporarily put aside. The phenomena which he discovered and elucidated have formed the basis of much important work since that time.

I may say in passing that he was the first to suggest and urge the use of insulating oil in transformers.

In looking over the list of old patents recently, I came across a patent to Professor Thomson which I believe represents the first use of a compensator or autotransformer. He called his device an "electric potential differentiator" as it was a device by which he could produce any desired potential differences within the limits of the circuit windings.

About this time he took out a patent for placing a transformer in a ventilated fireproof cell or apartment, a method which has since been adopted in many instances.

I have now very imperfectly sketched the pioneer work principally of the Thomson-Houston Company between 1880 and 1888. About this time the companies and inventions of Van Depoele, Bentley, Knight, Eickemeyer, Brush, Bradley, and others, were obtained, and a period of enormous expansion entered upon, which would take many hours to describe even in the briefest possible manner.

I have said nothing about the beginning of that most important and interesting application of electricity—the propulsion of street cars; and the application by VanDepoele of the carbon brush, which probably had more profound influence upon the development of the railway motor and of the entire line of commutating machinery than any other single discovery or invention.

I would like to go into more personal

matters and tell you how we obtained Mr. Emmons, Mr. Potter, Dr. Steinmetz, and many others who are so well known to you and who have contributed so much to this company's success, but as it would perhaps be a long story and exhaust your patience, I will reserve it for another occasion.

Annual and Anniversary Dinner, Hotel Astor, New York, March 11, 1909

The Institute will celebrate the completion of its first quarter of a century with an anniversary dinner at the Hotel Astor, New York City, March 11. The annual dinners of the Institute have always been extremely successful, while the historical character of this affair promises to make the occasion more than usually interesting. President Ferguson has appointed Mr. T. C. Martin chairman of the dinner committee; the other members appointed are: Messrs. T. Beran, M. Coster, M. M. Davis, H. A. Foster, G. A. Hamilton, R. T. Lozier, W. McClellan, F. A. Muschenheim, H. W. Pope, C. W. Price, F. A. Scheffler, E. A. Sperry, A. Spies, A. Williams and G. H. Guy, secretary. The committee is already busily engaged making its plans and arrangements. The price of the dinner, for which an excellent menu has been provided, is $5, including one wine, cigars and cigarettes. The tables will seat eight or ten persons. As usual on these occasions, ladies will participate, and an attendance of at least five or six hundred is expected. There will be only a few speeches, and these will be given by men of national prominence. Special attention is being paid to decorations, music and the souvenir menu. The following are the names and chairmen of the special sub-committees: Speakers and Menu, T. C. Martin; Reception, M. Coster; Finance, G. A. Hamilton; Tickets and Seating, R. T. Lozier; Decorations, A. Williams; Press and Music, G. H. Guy; Old Timers, E. A. Sperry. The speakers will include President Ferguson, Professor Elihu Thomson, and Dr. A. C. Humphreys, President of the Stevens Institute of Technology. The Sections and Branches have been asked to have a representative present if possible; and invitations have been extended to sister engineering societies.

Sections and Branches

ARMOUR INSTITUTE OF TECHNOLOGY BRANCH

At the regular meeting of this Branch, held January 7, 1909, Mr. A. P. Strong read a paper on "The Design of the Conduit System for a Multi-office Telephone System." He first took up the two methods of laying conduits; the one based on present needs, and the other on those of the future. A method of making estimates of future business from the population and conditions in the districts under consideration was discussed. The question of deciding between a central office system and a multiple office system was then considered, and it was shown that the conditions in a large city favor the latter. The economical distribution of office was the next point taken up, and the conclusion was reached that, in general, the best location is at the line center or center of distribution. The method of laying out the conduit routes was explained. It was shown that the general method is to select a straight line route unless the expense of repairing the paving on such a route would increase the cost above that of another route. In considering the various kinds of paving it was demonstrated that asphalt is the most expensive and difficult to repair. The determination of the number and size of the trunk lines between offices was taken up in detail. This was followed by a description of the method used to determine the amounts of different sizes of wire needed for lines from an office keeping the resistance per line approximately constant for various distances. Cost estimates on these lines and on the trunk lines were discussed.

The second January meeting of the Branch was held in the engineering societies' rooms on Jan. 21, 1909 at 8.15 p. m. A motion was carried to give a banquet for the Branch, and Messrs. E. B. Crane and H. Rose were appointed a committee to arrange details. Mr. T. C. Van Etten was appointed to investigate and arrange for picture of the members of the Branch in the *Integral.*

Mr. H. Rose, '09, then read a paper on " Third Rail Practice on Electric Railways." A comparison was made between the third rail and trolley-wire as distributing agents on 600-volt high-speed interurban roads operating on private right of way. The arguments presented indicated the supremacy of the third rail for service, on the ground of facility of large current collection, low maintenance, simplicity, freedom from strains due to temperature changes, and low first cost as compared with a trolley system of equivalent conductivity.

The location, dimension, section of rail, and construction, were described on various third rail roads. Special types were discussed and their relative advantages pointed out. The factors determining conductivity, such as chemical composition, bonding, jumpers, etc., were also discussed.

The paper compared the various types of protected and unprotected overrunning and underrunning contact rails with reference to operation. Types and materials of insulators were discussed with reference to economy and serviceability.

The various methods of sectionalization and interconnection were described with diagrams, and their relative merits cited. The automatic sectionalization as used on the Baltimore and Ohio electrification was described in detail of operation.

Several points of interest regarding recent methods of insulating and protecting the third rail were brought out in the discussion which followed the paper.

A special meeting was held in the physics hall, January 22, 1909, with an attendance of 74 members and visitors. Dr. H. B. Thomas read a paper, illustrated by lantern slides, on the subject of " Resuscitation from Electrical Shocks."

Dr. Thomas went very thoroughly into a preliminary analysis of the conditions, causes, and effects of an electrical shock, from physiological and medical pionts of view. A brief study was then made of the nerve and muscular structure of the human body as a preliminary to the discussion of the proper treatment of a person injured in this way.

Three hypotheses were carefully considered with reference to possible resuscitation; first, that there has been a hemorrhage in that part of the brain controlling the respiratory center; that the blood has caused pressure on the nerves which control the lungs, thus stopping respiration; secondly, that there is produced a paralysis of the vasomotor nerves causing a fall in blood-pressure, and in this way an interference with both the respiratory and heart action; thirdly, that the condition is due to the influence of the current on the nervous system, which interferes with the mechanism of the various organs affected, especially the heart; that is, the current may effect the heart muscles themselves, producing a deadly fibrillary contraction.

With these hypotheses as a basis, the speaker discussed, under different circumstances, the advantages and disadvantages of such methods as those of Marshall Hall, Sylvester, Shafer, and Howard. He finally showed the very superior advantages of a modified combination of the Schafer plan with that of Sylvester; the position of the body resembling somewhat that employed in the Shafer method but being such that allowed the stomach to empty into the intestine; the movements of the arms were those recommended by Sylvester; there were also suggested a heart massage as far as can be obtained by external means. The paper was illustrated by lantern slides from subjects treated by this modified method.

It was unanimously agreed by all those present that the subject was of such importance that it would be well to give each student personal instruction in it, under the supervision of the Institute's medical director.

At the close of the meeting a unanimous vote of thanks was given Dr. Thomas for his excellent paper.

BALTIMORE SECTION

The regular monthly meeting of the Baltimore Section took place at Johns Hopkins University, with a total attendance of 44, Dr. J. B. Whitehead presiding. Two papers were read: "Railroad Signaling and Protective Apparatus", by Mr. John S. Holliday of Pittsburg, and "Synchronous Commutation as a Method for Alternating-Current - Direct - Current Transformation", by Dr. John B. Whitehead.

BOSTON SECTION

There was the usual good attendance at the meeting of the Boston Section held January 20, 1909. The chairman, Professor A. E. Kennelly, introduced Mr. J. H. Corning, of Boston, who gave a talk on "Some Electrical Operating Features of the Boston Elevated Railway Company's System", handling the subject very ably. At the close of the discussion on the paper, Professor Kennelly presented Mr. Ralph W. Pope, of New York, secretary of the Institute. There having been some talk of the Boston Section uniting with the Boston Society of Civil Engineers in the erection of a joint engineering building, Mr. Pope took advantage of the opportunity afforded by an invitation to visit the Pittsfield Section, to touch also at Boston, and detail the experience of the Institute with the new Engineers' Building in New York City.

CHICAGO SECTION

The Chicago Section met on January 21, 1909, Mr. H. R. King in the chair. Prior to the talk of the evening Chairman King suggested that action be taken on the executive committee's recommendation that two members be elected on that committee to replace two members retiring. The executive committee having considered nominees, proposed Messrs. E. N. Lake and T. D. Niece. The nominations were approved and the two nominees elected.

Mr. King then introduced Mr. James N. Hatch, who presented a paper on "The Application of Electricity to the Rapid Handling of Ores." Mr. Hatch having made a very careful study of the subject, delivered an instructive and entertaining address. Upward of 100 stereoptican views illustrating the paper were shown. The collection of views is said to be the finest on the subject in existence.

UNIVERSITY OF CINCINNATI BRANCH

A meeting of the University of Cincinnati Branch was held in the engineering hall of the university on January 19, 1909. A committee was appointed to confer with the head of the electrical engineering department as to the advisability of establishing a Journal Class to meet once a week, the second meeting of the class each month to be a regular Branch meeting. It was proposed that the attendance of all electrical students be made compulsory. The business meeting was followed by the presentation of a paper by Mr. Clingman, on the Tirrill regulator, which brought forth considerable discussion by Messrs. Beidinger, Powell and Dr. Taylor.

CLEVELAND SECTION

Owing to the inability of the speaker scheduled for the regular meeting of the Cleveland Section January 18, to be present, the meeting was postponed to January 25, 1909. At this meeting the subject of a change of meeting place was voted upon, with the result of 27 to 18 in favor of continuing at the Case School of Applied Science.

The principal feature of the evening

was an address ably presented by Mr. J. G. Mitchell, on " Development of Telephone Instruments and Switchboards." Mr. Mitchell's talk was illustrated by drawings and diagrams, and he covered the subject admirably. The paper was followed by informal talks and a general discussion by those present in the course of which some interesting information on the construction and operation of large exchange-boards was brought out.

University of Colorado Branch

The regular meeting of the Branch was held in the engineering building of the university on February 4, 1909, with Chairman Watters presiding. Mr. Ward Rondolf read a paper on " Small Motors for Industrial Purposes." Mr. John Ritter gave an informal talk describing the Boulder sub-station of the Denver and Interurban single-phase railway. He explained the method of regulating the voltage on the auto-transformer, and told about the special devices for starting the 275 kw. synchronous motor.

Fort Wayne Section

This Section held its regular monthly meeting on the evening of January 14, 1909. In the absence of Mr. E. A. Wagner, Vice-chairman Kline occupied the chair. Several minor business matters were considered and disposed of, after which Mr. L. D. Nordstrum was presented and read a paper on " Some Considerations Involved in the Design of Direct-Current Generators and Motors." The paper dealt with the designing of new machines and the re-designing of a line of old motors or generators. The speaker presented the question both from the standpoint of the cost involved in the design of a line of machines, and the total weights and the weights of the copper and iron. He touched also upon the considerations involved in the design due to the heat losses in the machines. Messrs. J. J. Kline, E. A. Barnes, J. V. Hunter, A. L. Hadley, and J. H. Haberly, took part in the discussion on the paper.

Ithaca Section

The regular meeting of the Ithaca Section was held on Jan. 25, 1909. Mr. M. M. Goldberg, a graduate student in the university, and an alumnus of the University of Munich, delivered a paper on " Variable Speed Induction Motors." This paper was based partly upon the convention paper of Mr. H. C. Specht, on " Induction Motors for Multispeed Service with Particular Reference to Cascade Operation." Mr. Goldberg outlined clearly the principles of induction motor operation, giving a simple mathematical treatment of the induction motor based upon the rotating field. By this means he showed what would be necessary to change the speed of such a motor, explaining why an increase of secondary resistance is not a practical means of reducing speed. He then outlined the various methods used for obtaining several speeds from the same motor, pointing out the objections to each. In the course of the discussion which followed the paper, Professor V. Karapetoff gave a clear exposition of the application of the circular diagram to induction motors operated in cascade. From the circular diagram Professor Karapetoff was led to differ from some of Mr. Specht's conclusions. He also enlarged upon the use of the synchronous motor, synchronous converter and Heyland motor in combination with the induction motor, for the production of variable speed at high power-factor.

The paper and discussion brought out numerous questions, the answers to which were of interest. The meeting was one of the best, from a technical standpoint, that has recently been held by the Section. It illustrated an important principle in the conducting of University Branch meetings; namely, that a preliminary discussion of the general subject should prepare the way for a more specific study of engineering practice.

The next feature in the work of the Section will be the second annual dinner, to be held early in February. Mr. D. B. Rushmore will be the guest of honor. He will deliver a technical lecture before the Section in the afternoon, which will be followed by the dinner at six o'clock. The Section is also expecting a visit from Mr. Frank J. Sprague, who will speak informally on " The Railway Electrification Problem."

UNIVERSITY OF KANSAS BRANCH

A meeting was held by the members of this Branch on January 21, 1908, with Mr. Ray Jones as presiding officer, and an attendance of 15. The subject presented was Professor Thomson's Institute paper on " Conditions Affecting Stability in Electric Lighting Circuits." Some discussion followed the paper, led by Messrs. W. J. Wilder and Roy Liston.

LEWIS INSTITUTE BRANCH

There was an unusually large attendance at the meeting of this Branch held on January 20, 1909, about 425 members and visitors being present. Mr. Ralph Walker acted as chairman. Mr. Harry B. Gear gave a talk on " Transformers and Secondary Distribution." He called attention to the transformer in electrical work, ranking it next to the generator. By increasing the distance to which electrical power can be carried economically it becomes possible to supply a very large territory from a single station. In the early days, in the downtown districts of Chicago there were four direct-current steam stations. There are now several times that number of synchronous converter stations, and were not transformers and therefore alternating current available, these would all have to be steam stations. In the first alternating-current lighting systems the transformers usually had 50-volt secondaries. Owing to the heavy line loss with this low voltage, the transformers had to be located close to the consumer, and for this reason it was customary to hang a transformer near each building, which resulted in a very expensive and inefficient installation. Later came the three-wire 110-220-volt secondary, which made it possible to supply a number of consumers from one transformer, and by taking advantage of the " diversity factor " it became possible to supply a given district with a very much smaller amount of transformer capacity. In this way a few large transformers take the place of many small ones, the first cost and installation cost are much reduced, and the efficiency is better. It is not good policy, however, from an economical standpoint, to cover too large a territory from one transformer. In illustrating this the speaker cited a case of two adjoining city blocks (600 feet), and worked out a comparison of cost, first with one transformer for both blocks, and then with a transformer in each block. In the first case the transformer was cheaper, and the copper more expensive, than in the second case. The practice of the Commonwealth Edison Company is to locate one transformer in the center of each block and run a three-wire circuit 300 feet in each direction. No attempt is made to figure the line losses in such systems. The company makes a practice of putting up certain standard lines more than large enough to take care of the existing loads, and as the load grows on these lines, simply increases the transformer size from time to time. Three-wire circuits are not used unless more than 40 lights are to be supplied. If any service calls for a larger capacity than 50 kw., two or more transformers are put in parallel to supply it. It is not the rule to operate motors on lighting circuits on account of the disturbing effects of the motor currents. Only motors smaller than 0.5 h.p. are put on lighting circuits. For motors larger than 0.5 h.p. and up to 15 h.p. the open delta is used. For still larger sizes three transformers are used. In the discussion following the lecture, Mr. Gear explained the method of splitting off single-phase lighting feeders from a trunk three-phase four-wire feeder. He showed how four voltmeter compensators are used and how they are set so that the station voltmeters read the voltages existing at the distant ends of the feeders. He stated that in some recent installations the voltage of each feeder is regulated automatically by means of a contact-making voltmeter.

LOS ANGELES SECTION

The Los Angeles Section held its December meeting at the University of Southern California. Forty-one members and 37 visitors were present at the meeting. After the reports of standing committees had been accepted, the paper of the evening, entitled " How Far Can We Go With Automatic Regulation on Our Electric System ", was read by Mr. J. A. Lighthipe. Mr. Lighthipe proved an ardent advocate of automatic control. Messrs. Glasgow, Wood, Hoag, Wiatt, Walton, Scattergood, Northmore, Cunningham, Benedict, and Bowker, discussed this paper. Mr. Ralph Bennett abstracted the Institute paper on " Electric Heating ", by Mr. W. S. Hadaway, Jr. Mr. Cox, in discussing the paper gave some of his experiences in the city of Ontario, California, where electric heating for all purposes has proved a commercial success. At the conclusion of the meeting the chairman, Mr. C. W. Koiner, announced that it had been decided to make the January meeting a social event.

The Section held its mid-winter meeting at the Pacific Electric Grill on January 19, 1909. The meeting took the form of an informal dinner and smoker, followed by a social hour with the " wits " of the Section. One hundred and twenty-nine members and visitors accepted the invitations sent out.

Mr. V. L. Benedict, chairman of the entertainment committee, was largely responsible for this very successful meeting. The " Agony Quartette ", Mr. Benedict's creation, made a decided hit, especially with their parody rendition of " Bible Tales " which was a travesty on some of the local celebrities of the Section.

Mr. W. J. Clark of New York gave an interesting talk on " Heavy Traction." The evening's entertainment concluded with a lecture and demonstration on high-potential, high-frequency apparatus, by Mr. H. LaV. Twining.

MADISON SECTION

The first meeting of the Madison Section after its reorganization as a Section took place on the evening of January 27, 1909, in the Madison City Library building. There was an attendance of 42 members and visitors, and an interesting program was carried out. Professor Elihu Thomson's Institute paper on " Conditions Affecting the Stability of Electric Lighting Circuits " was abstracted, and an original paper on " The Design of a Transmission System for the Edison Electric Properties of Southern California " was presented by Mr. F. K. Brainard. The latter paper brought out a number of the more important considerations in connection with the design of such a system, and led to an interesting discussion.

Mr. C. E. Carter, the chairman of the Section, announced that he was leaving Madison to take a new position with a Colorado power company and would therefore have to resign his office with the Madison Section. Mr. Carter's resignation was accepted, but the election of his successor was deferred for a month

MEXICO SECTION

The second meeting of this Section was held at the American Club on January 29, 1909, with all of the members present. It was also the occasion of a banquet, and if the elaborateness of the menu may be considered an indication, the members must have enjoyed themselves thoroughly. The banquet was followed by a discussion on Professor Elihu Thomson's Institute paper, " Conditions Affecting Stability in Electric Lighting Circuits ". which was abstracted by Mr. A. E. Reynolds.

MINNESOTA SECTION

A meeting of this Section was called at short notice, in order that the members might avail themselves of the opportunity offered the Section by the presence in Minneapolis, of Mr. S. E. Doane, of the National Electric Light Association. Owing to the shortness of the time, however, the attendance was small, and the whole evening was devoted to an informal discussion on the subject of incandescent lamps.

UNIVERSITY OF MISSOURI BRANCH

The Institute paper " The Log of the New Haven Electrification ", by W. S. Murray, was the subject of discussion at the meeting of the University of Missouri Branch held January 15, 1909. Professor H. B. Shaw, chairman, presided, with a larger attendance than usual. The paper was presented by Professor Shaw, who touched also upon the operating characteristics of the single-phase commutator motor. Professor A. E. Flower detailed the methods used in eliminating troubles with line insulators and circuit breakers. Mr. McAdam outlined the general scheme of car wiring used in single-phase systems, and mentioned some operating difficulties encountered in practice. Mr. Schmander discussed the question of using copper or steel trolley-wire in presence of vapors, instancing practice in certain localities. Professor Shaw pointed out the limitations of the steam locomotive in grade climbing, and emphasized the special adaptability of electric motors for such service. In the general discussion some time was spent in a consideration of electric locomotives both for direct- and alternating-current systems, and the general question of electrification of steam roads was touched upon briefly. Time did not permit the taking up of some other phases of the subject, and the meeting was finally adjourned while interest in the paper was yet keen. Messrs. Bowles, Busey, Krausnick, Lewis, Mount, and others, took part in the discussion. The meeting was the most successful held this season.

MONTANA AGRICULTURAL COLLEGE BRANCH

Mr. H. H. Cochrane, electrical engineer, delivered the address at the regular monthly meeting of this Branch, held on January 15, 1909. About 35 members and visitors were present. Mr. Cochrane's subject was " Transmission Lines." By figures and practical examples he showed the conditions necessary to make the installation of a power plant and transmission lines a success. He then took up the different kinds of lines, showing what construction and route would be advisable under different conditions of location, with respect to mountains, rivers, large cities, railroads, etc. He explained the electrical and mechanical design of steel towers for transmission lines, and the regulation of the tension in the line itself. The various types of insulators were discussed, and the points of difference in their construction and efficiency shown. Before adjourning, Mr. Cochrane made tests with several types of insulators, showing the results of subjecting them both wet and dry to voltages up to 150,000.

NORFOLK SECTION

The Norfolk Section held a meeting on December 18, 1908, at Hotel Victoria. Previously to the meeting a dinner was served in the hotel dining room. Twenty-two members and friends were present at the dinner. At the meeting which followed, the secretary was authorized to secure a permanent meeting place. Mr. H. W. Hough presented a paper on " Transformer Testing ", which proved too long, however, to be covered at this meeting, and it was decided to renew the subject at a future time.

OREGON AGRICULTURAL COLLEGE BRANCH

At the meeting of this Branch, held December 22, 1908, Mr. W. A. Schoel presented an abstract of the paper read by Mr. W. S. Murray at the December meeting of the Institute, entitled " The Log of the New Haven Electrification." Mr. Schoel was followed by Professor T. M. Gardner, with a talk on " The Future of Electric Railways in Oregon." On conclusion of the program refreshments were served. At this meeting it was voted to admit local members to the Branch and allow them the right of the ballot in local elections. Thirty-five members and visitors were present.

Local conditions prevented many members from attending the January 25th meeting, which nevertheless proved interesting. Mr. Knopf abstracted the Institute paper by Professor Thomson on " Conditions Affecting Stability in Electric Lighting Circuits."

The first regular meeting in February was held in the mechanical hall on February 1. The program was a series of short talks each followed by a brief discussion.

Mr. W. A. Schoel spoke of " The Wreck of the Cazedero Plant." Illustrations were used to show the terrible damage done at that plant.

Mr. F. R. Becker introduced as his topic, " The Use of a Single Direct-Current Generator on a Three-wire System."

The laboratory has recently received a new synchronous converter, and Mr. E. V. Hawley devoted a few moments to a description of the machine.

Mr. S. H. Graf presented a few notes on the single-phase commutator motor.

Mr. Graf was followed by Dr. Weniger who in conclusion of the exercises spoke on " The Industrial Activities Along Electrical Lines in Germany."

PITTSBURGH SECTION

The regular monthly meeting of the Pittsburgh Section was held in the Carnegie Institute on January 12, 1909, Chairman W. Edgar Reed presiding. The meeting was preceded by an enjoyable little social dinner at the University Club. The subject of the evening was introduced by Mr. William Hoopes, in an original paper entitled " Electric Furnaces ", which was illustrated by lantern slides. The paper proved of unusual merit, and Mr. Hoopes was complimented upon the manner in which he handled the subject. The iron and steel and kindred interests were well represented in the audience, and the discussion which followed indicated the interest taken in the paper. It was announced that the subject for the February meeting would be " Electric Signaling ", an original paper by Mr. L. F. Howard.

PITTSFIELD SECTION

Over 100 members of the Pittsfield Section attended its second annual dinner at the Wendell Hotel on January 22, 1909. No efforts were spared to make it a success, and the meeting fulfilled all expectations. The speakers were: C. C. Chesney, W. S. Moody, R. W. Pope, T. D. Lockwood, and Paul Spencer. Mr. Chesney spoke on the future of Pittsfield. Mr. Moody's subject was " Some Requisites of a Designing Engineer." Mr. Lockwood asked Mr. Moody if a designing engineer was one who had designs on the job of the boss and was assured in the affirmative. Mr. Pope spoke on " Inventors I Have Known ", recounting a number of humorous anecdotes, besides mentioning some of the most prominent pioneers in the electrical field, of his acquaintance. Mr. Lockwood's topic was " The Present Patent Situation ", which he handled in an able manner, but before getting down to the situation he entertained those present with some humorous reminiscenses. The last speaker, Mr. Spencer, who is chairman of the Sections Committee of the Institute, addressed the audience on "Section Organization." It was midnight when the speaking was over.

At the meeting of February 10, 1909, the members of the Section had the pleasure of hearing an address by Dr. W. R. Whitney, on the subject of "Chemical Elements."

During the opening remarks Dr. Whitney called attention to the various forms of matter known as elements, numbering between 75 and 77, and pointed out some of their different characteristics, such, for example, as atomic weights, melting points, etc. While 52 out of this number may be classified as metals, but a small part of them, such as iron, copper, zinc, aluminum, etc., are all well known, while the balance come under the heading of metaloids and gases.

Years of careful study has developed the fact that the elements while having many different characteristics all bear certain definite relations to each other and may be arranged in natural groups according to their atomic weights. So perfectly has this arrangement been worked out that there is but one place in any group into which a given element will fit and it is therefore possible to predetermine with great accuracy the character of a number of elements which are known to exist, but have not as yet been discovered.

This knowledge of the inter-relation between elements is also of great assistance in carrying on investigations as it oftens points out the way to new discoveries and new uses to which various materials may be adapted.

Interesting facts were brought out, as to the melting points of some of the more common elements, such as hydrogen, which melts at below minus 200 degrees centigrade, to carbon, which is believed to have a melting point of about 3500 degrees centigrade. The latter temperature, however, is by no means the highest which exists. Recent experiments and calculations place the temperature of the sun at over 6500 degrees centigrade while that of some of the stars is as high as 30,000 degrees centi rade.

Perhaps one of the most fascinating branches of chemistry and physics, the study of which is destined to add greatly to our present knowledge of matter and the universe, is that of the spectrum. Investigations along this line have enabled us to determine with absolute certainty the elements which are present not only in the sun and nearby planets, but in distant astral bodies as well, and to discover many of the newer elements such as relium, argon, etc.

One of the most startling discoveries that spectrum analysis has led to is the fact that many of the stars are losing their heat year by year and will eventually become entirely cold, while others, due to friction of the rapidly moving particles of which they are composed, are gaining heat and each year becoming hotter. In this way the equilibrium of the universe is being maintained.

After closing his lecture, Dr. Whitney entertained the Section with electrical and chemical experiments showing that electrolysis takes place not only in chemical combinations, but in suspended inert matter as well.

SAN FRANCISCO SECTION

The extremely unfavorable weather conditions prevailing on the coast interfered seriously with the operation of lighting, telephone and telegraph interests, with the result that many of the members of the Section on the staffs of the above mentioned companies were out of town and unable to be present at the regular meeting of the Section, held January 22, 1909. Nevertheless there was an attendance of 50, and in the absence of Chairman Burkett, Mr. A. H. Babcock presided. The executive business consisted of an abstract of the Atlantic City discussion on Sections, which was presented by Mr. Babcock. The abstract was then turned over to the executive committee with the recommendation that they put into effect some of the suggestions contained therein.

The business session was followed by the delivery of a paper on " Lighting with Metallic Filament Lamps." Mr. E. L. Sherwood was to have read the paper, but was unable to reach San Francisco in time for the meeting, and Chairman Burkett being floodbound, Mr. Babcock was asked to preside. The paper gave some valuable figures, especially in comparing the tungsten lamp with the old style carbon filament lamp, and the curves and tables of comparison were interesting. Messrs. C. L. Corey, S. B. Charters, G. C. Holberton, C. J. Wilson, S. L. McMeen, and A. H. Babcock, took part in the discussion.

SCHENECTADY SECTION

On January 7, Mr. G. Faccioli delivered a most interesting lecture before the Schenectady Section. Mr. Faccioli's lecture was devoted particularly to the calculation of reactance of inductive apparatus, the derivation of the formulas, and their application. The attendance was about 200, and his subject evoked a great deal of interest and considerable discussion.

On January 21 the Section had its first smoker of the season. The purposes of this smoker departed so radically from the usual intent of Section meetings that the officers were very glad to shirk all responsibility by placing the matter entirely in the hands of the entertainment committee.

In arranging its course of lectures for this season, it has been the intention of those who had the matter in charge, to lay out a course of lectures covering a diversity of subjects such as would appeal to all classes of membership. This has resulted in that one lecture being attended largely by a class whose interest was aroused by that particular lecture, while the lecture on some other subject would be attended by some other class. The effect of this arrangement has been that while the Section has always had a good attendance at each meeting, it has never been possible to get out a very large percentage of its total membership. The smoker and the splendid program arranged by the entertainment committee seemed to appeal to a large portion of the membership, so much so that the hall was crowded to its doors. As near as could be estimated, about 700 attended the smoker. Neither engineering subjects nor routine matters was taken up, but the interest aroused by the entertainment was sufficient to hold the crowd from 8 o'clock until about 10:30 p.m. The smoker was such a success that the Section will probably arrange to have another one later in the season.

On January 28 Mr. C. D. Knight, delivered a most interesting lecture, covering as fully as the time permitted. the entire field of controlling apparatus for both alternating and direct-current electrical equipment. About 250 attended the meeting and were very much interested in Mr. Knight's description of control apparatus, which covered both the design and practical application of these devices. Mr. Knight had a splendid collection of lantern slides which served very forcibly to illustrate his remarks.

On February 4 the Section had the pleasure of hearing a paper by Mr. Percy H. Thomas on "High-Tension Transmission." Mr. Thomas has made a special study of this subject, and covered every phase of the transmission problem in such a manner as to arouse the greatest interest and evoke considerable discussion at the conclusion of the paper.

He covered broadly the principal questions that have to be considered by the electrical engineer in connection with a specific high-tension transmission. The feasibility and earning power of the system, the actual design of an adequate plant, its cost, the underlying principles of design, the line, static effects, switching protection, and various high-voltage phenomena which arise in connection with such transmission. About 200 members were present.

At the meeting on February 11 Mr. W. S. Andrews delivered a lecture on " Radiation."

Mr. Andrews' study of this subject has covered a period of a great many years, and his writings and investigation in the field are known throughout the entire country. The lecture was accompanied by an extremely interesting series of demonstrations, made possible by an admirable collection of apparatus which Mr. Andrews has collected during his study of this subject. The lecture was such as to appeal equally as well to those of a practical turn of mind as to those theoretically inclined. It covered broadly the entire subject of radiation, starting in with the low-frequency wave and passing up the entire scale through heat, light, chemical and X-ray.

The attendance was about 350, and at the conclusion of the lecture a large number stayed over to ask for a repetition of some of the demonstrations, and for additional demonstrations which Mr. Andrews stated in his lecture could not be shown at long range. Mr. Andrews took great pains in setting up his apparatus to start in some days before the lecture, and the result was that every experiment, of which there were a great number, was made without a hitch. The great pains which Mr. Andrews took to have everything just right in advance of the lecture added a great deal to its success.

SEATTLE SECTION

The chief business at the meeting of this Section on January 16, 1909, held in the rooms of the Chamber of Commerce, was the election of officers for the ensuing year. Reports submitted by the officers disclosed a gratifying increase in the membership and attendance of the Section during the past year. The report of the local secretary showed that the increase in the membership for the State of Washington was slightly greater than the average increase for the Institute throughout the country. The report showed further that the increase for the State for the year ending February 1, 1908, was 30 per cent., which percentage seems likely to be realized for the year ending February 1, 1909.

Following a discussion of the arrangement for a new meeting place, made necessary by the removal of the Chamber of Commerce to its delightful quarters in the recently completed Central Building, Mr. C. A. Whipple moved that the local secretary be empowered to confer with the Chamber and with the Pacific Northwest Society of Engineers.

A committee was next appointed to draw up and transmit to the former local secretary, Mr. W. S. Wheeler, resolutions of regret and sympathy for his recent bereavement in the death of his wife. Mr. Whipple spoke earnestly of Mr. Wheeler's work in the upbuilding of the Section, the value of which is fully realized and appreciated by its members.

The annual election then followed, preceded by the usual nomination by ballot, with a second ballot upon the three nominees receiving the highest number of votes. The officers for the year just expired were re-elected by large majorities, and a vote of appreciation was tendered by the members present.

Mr. W. S. Hoskins brought up the matter of an industrial power meeting. The subject, " Motor Application in the Northwest ", was decided upon for the March meeting.

ST. LOUIS SECTION

The St. Louis Section held its January meeting on the 13th, at the Engineers' Club. The attendance was lighter than usual, probably due to bad weather. The presiding officer was Chairman A. S. Langsdorf. Mr. H. Weichsel read the paper of the evening, the subject of which was the testing of large induction motors. Various methods of testing were described, with explanations of the connections, instruments, and apparatus used. It was shown that owing to the large amounts of current required for direct tests the methods most generally used are indirect.

STANFORD UNIVERSITY BRANCH

On the evening of December 8, 1909, the Branch met at the home of Professor Harris J. Ryan. After the business routine was completed, Professor Ryan spoke on the course to be pursued by an electrical graduate the first few years immediately following his graduation. As this is a question of much importance to the undergraduate, the subject was timely, and Professor Ryan's remarks were appreciated by those present. Mr. A. J. Gowan, the secretary of the Branch, presided at this meeting.

On January 19, 1909 another meeting was held, in the university. The executive committee was detailed to provide for a tour of inspection by the senior class in electrical engineering through the power plants of the bay region.

This was followed by a description by Mr. Hoskinson, of " The Western Pacific Power Development on the Feather River, California." Mr. Hillebrand contributed " Business Routine as Applied to Engineering." The meeting closed with a short talk by Mr. Charters, on " The Life of an Apprentice."

Another meeting was held on February 2, in the engineering hall, at which Mr. Montgomery read a paper on " The Means Taken for Lightning Protection on Transmission Lines." Mr. Bradley was next called upon and he gave an excellent description of " Fifteen-Cycle Electric Power as Furnished by the Visalia Electric Company."

SYRACUSE UNIVERSITY BRANCH

At the meeting of January 7, 1909, Professor H. Monmouth Smith presented a paper on " Recent Progress in Artificial Illumination." Professor Smith showed in operation the most recent types of gas and electric lamps and shades, and by tabulated data illustrated the results of various tests. The types shown included the Welsbach upright and inverted lamps, the carbon, metalized filament, tantalum, Tungsten, and helion incandescent electric lamps, also the flaming arc, the magnetite, and the mercury vapor lamps. The subject was evidently one of interest, as there was a large attendance.

At the February 4, 1909 meeting Mr. Richard C. Leake gave a demonstration of the apparatus invented and patented by him for the selective operation of electric circuits. Mr. Leake's invention, located at the sending and receiving stations of a wire or wireless circuit, enables any one of a number of circuits at the receiving station to be closed or opened at the will of an operator at the sending station, thus bringing any work that can be done electrically under absolute control from a distant point. This selective closing of circuits is accomplished by transmitting impulses of varying time-lengths over the operating circuit, these impulses assuming a character very much like the ordinary telegraphic characters, each series of impulses selecting and closing some one circuit at the receiving station. The principle underlying this control is the use of one or more retarding actions within the mechanism at the receiving station. These retarding actions permit a circuit being controlled only during a prolonged open or closed operating circuit. The circuit thus controlled is the one selected by a rotating multiple switch actuated step by step through the action of a double bawl and ratchet movement, one position for each closed and open operating circuit preceding and including the prolonged open or closed operating circuit which terminated this series of impulses.

UNIVERSITY OF TEXAS

The first regular meeting of the Branch since the holiday vacation was held on January 15, 1909. There were present 19 members and two guests. After a brief business session Mr. B. E. Kenyon gave a description of the Laredo Light & Power Company's plant. He was followed by Dr. A. C. Scott, who described the new type of electro-magnetic gun which has recently received much attention in the current periodicals. This subject was discussed at some length, and the general impression seemed to be that such a piece of ordnance was impracticable. The queries in the Question Box were then taken up and discussed, after which the meeting adjourned.

Ninteeen members of the Branch attended a meeting held at the residence of Dr. A. C. Scott on the night of January 29. The program for the evening consisted of a review of the Institute paper " Some Engineering Features of the Southern Power Company's System." Mr. Watkins reviewed the paper. The remainder of the time was occupied in answering the queries in the " Question Box." After adjournment, refreshments were served, and all agreed at the close of the meeting that they had spent a delightful evening.

TOLEDO SECTION

At its monthly open meeting, held on January 15, 1909, in Builders' Exchange, the Toledo Section listened to an entertaining talk by Mr. C. C. Batchelder, of Schenectady, New York, on the manufacture of cement. The various steps in the process of manufacture were described by Mr. Batchelder, from the handling of the raw material to the finished product, all of which were illustrated by lantern slides. It appears that the manufacture of cement involves little labor, and the material is inexpensive, but the question of power is of great importance, and of the power employed by far the major portion is used in the grinding and pulverizing of the ball and tube mills, while the rotary kilns up to 180 feet long require relatively little power. The strong points in favor of electric drive, namely, efficiency, ease of manipulation, reliability and low cost of maintenance, although appealing to the cement manufacturer, in order to hold good the question of dust must be considered, but this difficulty has been successfully overcome in both direct- and alternating-current work, preference being given to the latter in that brushes are avoided. Many forms of individual motor drives were shown, direct, gear, and belt-connected. Views were shown illustrating the distribution of the cement industry from the eastern states to California.

TORONTO SECTION

The regular monthly meeting of the Toronto Section was held on January 22, 1909, in conjunction with the Society of Chemical Industry. It was preceded by an informal luncheon at the St. Charles Cafe, at which 43 members of the two organizations were present. After the luncheon the party repaired to the Engineers' Club, where the meeting was held. Seventy-six members were in attendance. An original paper was presented by Mr. J. C. King, of St. Catherine's, Ontario, entitled " Electro-metallurgical Processes." The paper covered the subject very fully, tracing the development of the electro-metallurgical industry from its earliest date. It was accompanied by a number of drawings of recent designs in electrical furnaces with a full description of each type and present-day practices. It was evident from the discussion which followed that the topic was one of great interest to those present.

URBANA SECTION

Mr. Louis A. Ferguson, president of the Institute was the guest of the Urbana Section at its January meeting held in the physics lecture room of the university on January 15, 1909. Mr. Ferguson was introduced by Professor Morgan Brooks, to an audience which taxed the capacity of the room. His lecture, entitled "Training the Electrical Engineer"; was not of a technical character, but more in the nature of a resumé of the qualities that go to make a successful engineer, not only in electrical lines, but in others as well. Mr. Ferguson pointed out that a technical education is an advantage, but not when it is acquired by the memorizing of details and data at the sacrifice of fundamentals. Its value does not lie in the knowledge obtained, but in the training acquired. Data and details are too soon forgotten, but the training is permanent; and with it, the technical man can solve any engineering or commercial problem. A technical training teaches the difference between right and wrong and enables the recipient to discuss problems intelligently and to decide them correctly. The statement heard so often, that technically trained men are not really successful, is not borne out by facts, as the alumni records of technical institutions of this and other countries show. Not very long ago the successful business man was the one characterized as a good fellow; that is changed now; the "man with the goods" does the business. Mr. Ferguson made the assertion that in 25 years the chief managerial positions in every large corporation will be filled by technically trained men. He specially emphasized the fact that the commercial side of engineering is equally as important as the purely technical one, and that to be in any degree successful a man must have as part of his training a thorough grounding in mechanical engineering, chemistry, hydraulics, civil engineering, languages, and business principles. In addition, he must possess a strong mind, a good moral character, and a healthy body. Mr. Ferguson furthermore urged engineers to engage in constructive public work of non-political character; to be loyal and respectful to their superiors, and fair to those beneath them; to cultivate tact, sincerity, earnestness, and to have a fixed purpose and work toward it in a straight line.

WASHINGTON SECTION

One hundred and ten members and guests attended the meeting of the Washington Section on January 12, 1909. This was the first regular meeting of the season, the previous meetings having been held in conjunction with other engineering bodies. The election of the new officers at the last official meeting, held in May 1908, was confirmed. The resignation of Mr. L. D. Bliss as secretary, and the appointment of Mr. H. C. Eddy as his successor, by the executive committee, was announced. The number of members of the executive committee was increased from three to five.

On conclusion of the business meeting, a paper was presented by Mr. B. F. Wood, on "The Electrical and Mechanical Equipment of the Washington Terminal."

WASHINGTON UNIVERSITY BRANCH

A meeting of this Branch was called for February 4, 1909, in the lecture room of Cupples Hall I. Twenty-five responded to the call. An illustrated lecture by Mr. C. A. Bulkeley, on the "Reconstruction of the Power Plant of Central High School", was the principal feature of the meeting. Mr. Bulkeley first explained the general layout of the three buildings; main building (old), manual training, and warehouse. In supplementing the former direct radiation system in the old building, two 10-foot fans of 140,000 cubic feet per minute combined capacity were installed, and the ducts from them connected to the ventilating flues already in the walls. A highs-peed 11-foot exhaust fan was placed in the attic to eliminate the foul air. The auditorium was equipped with a special washer fan which delivered warm air over a high partition at the rear of the stage. If the temperature should here fall under 70 degrees the full capacity of the tempering coils is turned on, and if below 68 degrees, the direct radiation is connected. The halls are lighted with 75 c-p. gem lamps under glass reflectors. The radiation rooms were fitted with four clusters, calculated to give a minimum of 2-foot candles at the desk level. The results of efficiency tests on the new generators were given, and the considerations which led to cutting over the load from the large to small units for most economical operation were pointed out. After the lecture the members adjourned to Section D, Liggett Hall, where light refreshments were served. A very enjoyable hour was spent before final adjournment at 11:30 p.m.

Worcester Polytechnic Institute Branch

The fifth lecture, this year, of the Worcester Polytechnic Institute Branch was delivered at the meeting of December 11, 1908, by Mr. F. W. Sawyer, of Boston. The subject was "The Gas Engine in the Small Central Station."

Mr. Sawyer dealt with experience and current engineering practice rather than with theory. He said that the large central station was generally a turbine station, and that the turbine had not proved as desirable in capacities much under 750 k.w. In these smaller stations the gas engine is sometimes found. There are two conditions where it may be especially advantageous to use the gas engine; first, in a natural gas district where the price of gas is seldom over twenty-five cents per thousand feet, and, secondly, where a gas and electric service is operated by a single company from a single plant. The next points taken up were the factors controlling the installation of the prime movers in the central station. The first and most essential point to be considered is that of reliability. The gas engine with a good, constant supply of clean gas may be considered as reliable, but an element of unreliability comes from the gas producer which cannot, in the present state of the art, be entirely depended upon for a constant uniform gas output. The second point to be considered is the net cost of output from the plant. This is dependent largely upon the load-factor of the station. If the load-factor is low, the gas engine will seldom be employed. The net output cost may be divided into the standby and the running cost. The running cost includes fuel, oil, waste, and a proportion of the repairs. The principal standby costs are interest, depreciation, and the larger proportion of labor. Economy in fuel is the chief advantage of the gas engine, and there is also some advantage in labor cost. Interest often runs as high as ten per cent. on actual capital under present financial methods. Depreciation, in the case of the gas power plant, may be more safely taken as ten per cent. at the present time, since advance in the art and better apparatus may render advisable the discarding, within a few years, of apparatus installed to-day. An ideal use for the gas engine to-day is in combination with a steam engine plant. The gas engine should be used to care for the average load and should be run as near as may be at full load, and the steam engine should be used to take care of fluctuating and peak loads and as a spare unit. The use of the steam engine may sacrifice running efficiency for the sake of low first cost, but reducing the standby losses of that part of the plant which has a poor load-factor will more than offset the sacrificed efficiency of its output. A scheme, which is somewhat novel, was suggested by Mr. Sawyer; namely, to use the hot jacket water, further heated by the exhaust gas, as boiler feed water for the steam plant. When the steam engine is not in use, instead of banking the fires this exhaust gas may be turned under the boiler and used to keep the water hot.

January 29, 1909. This was the regular January meeting, and about 200 were present to hear a lecture on " Wireless Telephony and Its Recent Development ", which was delivered by Mr. Leon I. Thomas. Mr. Thomas gave a resumé of investigations and practical work in wireless telephony from the crudest methods devised back in the '80's, capable of operating for 150 feet, down to the present marine type of wireless telephone suitable for distances up to 100 miles.

The use of parabolic mirrors to guide the sound generated at the focus was probably the first method tried. Considerable experimenting has been done with various forms of Bell's original photophone when a varying beam of light affects a selenium cell, Ruhmer of Berlin being notable among the experimenters along this line.

Dolbear's condenser method as well as Edison's similar scheme for telephoning from moving trains was described.

Practically as soon as Marconi made his first successful wireless telegraph experiments, thought was given to various schemes of telephoning by Hertzian waves. The spark methods were not satisfactory, however, for telephoning purposes, because the pause between sparks caused the resulting speech reproductions to be harsh and broken.

After the discovery of the direct-current arc method of generating continuous high frequency oscillations, more rapid progress was made, with the result that there are to-day two foreign companies and one in this country making apparatus operating on this principle. The high-frequency generator furnishes another means of generating continuous oscillations, this method being employed by Fessenden.

The De Forest wireless telephone system, using arc method, successfully operated over a distance of 60 miles at a test before the British Admiralty last September.

One of the foremost wireless telegraph and telephone experts in this country places the time of transatlantic wireless telephony within the next ten years.

PROPOSED PORTLAND SECTION

Recent communications received at the Secretary's office from Portland, Oregon, indicate that a vigorous movement is on foot at that place to organize a Section of the A. I. E. E. Foremost in the movement are Messrs. O. B. Coldwell, L. B. Cramer, F. F. Barbour, and W. S. Turner, all old Institute members. At a conference held by these gentlemen it was decided to arrange for a general meeting of the electrical men of Portland and lay before them the benefits to be derived from having a Section of the Institute in Portland. The meeting was held on January 28, 1909, in the patent room of the Portland Library Building, about 40 responding to the invitations. Messrs. Barbour and Turner addressed the meeting. As a result, 14 applications for election to membership in the Institute have been received from Portland since February 5. There are at present 15 Institute members there, and to organize a Section there must be at least 25. The new applications received more than make up this number. and therefore the outlook for a Section at Portland is very promising.

Local Representatives of the Board of Examiners

The growth of the Institute in recent years and the wide extension of its membership geographically have made it difficult in many cases for the Board of Examiners to pass with justice upon all applications for election as Associates and for transfer from the grade of Associate to that of Member.

In order to bring the examiners board into closer touch with the various sections of the country and the qualifications of members or applicants for membership in those sections, the following Local Representatives of the Board of Examiners have been appointed by the President:

W. C. L. Eglin, 1000 Chestnut Street, Philadelphia, Pa.
R. F. Hayward, Mexican Light & Power Company, Mexico City, Mex.
P. Junkersfeld, 320 Prairie Avenue, Chicago, Ill.
W. A. Layman, 2017 Locust Street, St. Louis, Mo.
F. V. T. Lee, 59th Street and College Ave., Oakland, Cal.
Charles E. Waddell, Biltmore, N. C.
H. W. Weller, New York Life Building, Montreal, P. Q.

Whenever it is considered necessary, the examiners will communicate with these Local Representatives in reference to the qualifications of individual applicants for election or transfer, and it is hoped that this procedure will result in the maintenance of the highest standard of membership.

This plan affords representation for the Board of Examiners in many of the important districts of the United States, Canada, and Mexico, and other sections will be covered from time to time by further appointments as may be necessary. All of the men listed are Members of the Institute and familiar with the requirements for both grades of membership, and applicants should confer with them whenever possible before filing formal papers with the secretary. This method of aiding the Board of Examiners should accrue to the benefit of the Institute by:

a. Raising the standard of membership and avoiding misunderstandings which now arise from time to time in connection with applications.

b. Excluding undesirable members.

c. Increasing membership through suggestion where obviously eligible candidates come within the notice of one of the Local Representatives.

Personal

Mr. William Pestell has associated himself with the Boston office of the Allis-Chalmers Company, 50 Congress Street, Boston, Mass.

Mr. Louis A. Ferguson, president of the Institute, has been elected one of the directors-at-large of the Chicago Association of Commerce.

Mr. Thomas L. Miller, consulting engineer, has removed to new offices, situate 9 and 10, Tower Buildings, Water Street, Liverpool, England.

Mr. P. Eveland has been transferred from the Leadville Light & Power Company, Leadville, to the Central Colorado Power Company, at Shoshone, Colo.

Mr. Thomas W. Winsor has been appointed expert electrical aid in the department of construction and repair, Puget Sound Navy Yard, Bremerton, Washington.

Mr. Ernest Gonzenbach, general manager of the Sheboygan Light, Power & Railway Company, Sheboygan, Wis., has been elected president of the Northwest Electrical Association.

Mr. Darrow Sage, formerly superintendent of the Park Row Building, has been appointed chief engineer of the Jersey City power house of the Hudson & Manhattan Railroad Company.

Mr. C. Olivetti, of the Ingegnere Industriale, Ivrea, Italy, recently paid a visit to this country, spending the months of December and January here. He sailed for home on February 10.

Mr. Louis Elliott, of the engineering department of the Central Colorado Power Company, retains his connection with that company upon the removal of its offices from Colorado Springs to Denver.

Mr. L. E. **Wheeler** has left the Maryland Electric Company of Baltimore, and is now with the Westinghouse Electric & Manufacturing Company at Pittsburg, in the detail and supply department.

Mr. **Everett H. Hendrickson**, formerly with the electrical department of the Mare Island Navy Yard, has recently become associated with the Rockland Light & Power Company, of Nyack, N. Y.

Mr. F. W. **Mack**, who was manager of the Storm Lake Electric Light & Power Company, Storm Lake, Iowa, has been appointed superintendent of the Hawarden Light & Water Department, Hawarden, Iowa.

Mr. S. D. **Coffin** has engaged in the hardware and implement business at French, New Mexico, under the firm name of Coffin and Jacobs. leaving the Western Electric Company, of Chicago, for this purpose.

Mr. H. S. **Evans**, until recently treasurer and general manager of the Oliver Manufacturing Company. of Philadelphia, Pa., is now located at Harrison, N. J., in the main lamp sales department of the General Electric Company.

Mr. **William H. Hoag** has connected himself with the H. W. Johns-Manville Company, in the electrical department, as salesman in the southern territory, with headquarters at 100 William Street, New York City.

Mr. W. I. **Reich**, mechanical engineer, of Pittsburg, has opened an office at 245 West 24th Street, New York City, and a shop at 23rd Street and 11th Avenue, New York City. His specialty is welding engineering.

Mr. M. R. **Davis**, engineer with the Westinghouse Electric and Manufacturing Company, has been transferred from their Denver, Colorado office, to the Salt Lake City office, as district engineer of that territory

Mr. T. **Whitehead**, lately in the engineering department of the Western Electric Company. Hawthorne, Ill., has taken a similar position with the Westinghouse Electric & Manufacturing Company, East Pittsburg, Pa.

Mr. C. J. **Heilman** is resuming his connection with W. R. Grace & Company, Valparaiso, Chile, South America, in their technical department. He was formerly with the General Electric Company in New York City.

Mr. J. P. **O'Donohue**, district electrician of the Postal Telegraph Company, at Boston, has been transferred to the electrical engineer's office of the same company in New York City, at its main office, 253 Broadway.

Mr. **Harry C. Estabrook**, of the construction department of the General Electric Company, is in Italy attending to the installation of the first 50,000-volt transformers in that country, for the Society Conti of Milano.

Mr. L. G. **Gresham** has been transferred from the commercial department of the Philadelphia office of the General Electric Company. to their New Orleans office, where he will continue the same line of work in the small motor department.

Mr. **Arthur L. Mudge**, who for several years has been connected with some of the larger electrical manufacturing companies, has joined the staff of Smith, Kerry & Chace, engineers, of Toronto, Ontario, and Winnipeg, Manitoba.

Mr. **James R. Wilson** left Niagara Falls, N. Y. the beginning of this year to take charge of the Middlecreek Electric Company, Sunbury, Pa., as superintendent. The company does a general lighting and power business in the adjoining towns.

Mr. A. G. McGregor has accepted a position as mechanical and electrical engineer with the International Smelting & Refining Company, with headquarters in Salt Lake City. He formerly served the Anaconda Copper Mining Company in the same capacity.

Mr. Ray Palmer, who has been treasurer of the Hendee Wire Brush Company of Milwaukee for the last three years, has sold out his interest in that company and accepted a position with the Chicago Malleable Castings Company of West Pullman, Chicago, Ill.

Mr. R. J. Andrus, who has been associated with the Washington Water Power Company as commercial agent, has accepted a position with the Yakima Valley Power Company, as superintendent of the Kennewick-Pasco system, Kennewick, Washington.

Mr. Lawrence H. Lee, until recently with The Connecticut Company of New Haven, has accepted a position with the Portland Railway, Light & Power Company, and is at present superintending the construction of a 7500 kw. sub-station in Portland, Oregon.

Mr. Henry Floy, consulting engineer of New York, has republished his interesting article entitled, "Tuxtan Oil Well Fire." This fire lasted for three months, consuming several millions of barrels of oil. The article first appeared in the *Engineering News* of December 10, 1908.

Mr. Joseph D. Shaw has severed his connection with the Pittsburg Railways Company and Allegheny County Light Company, of Pittsburg, Pa., and is now associated with The Fountain-Shaw Engineering Company, with head-quarters at 501 Binz Building, Houston, Texas.

Mr. F. J. Englehorn, who for the last three years has been employed by the Yukon Gold Company, in the Klondyke, has engaged in business for himself, and is now principal stockholder and manager of a hydroelectric lighting and power plant at Orofino, Idaho.

Mr. T. B. Morgan, who had charge of the electrical laboratory of the Transit Development Company, Brooklyn, N. Y., left that company on January 25 to take charge of the meter department of The Connecticut Company, and is at present stationed at Waterbury, Conn.

Mr. L. H. Conklin resigned on January 15 his position as general superintendent of the West Penn system of Pittsburg. He has accepted the position of general manager of the numerous properties controlled by the Scranton Electric Company, with headquarters at Scranton, Pa.

Mr. M. G. Carhart has severed his connection with the erecting department of the Westinghouse Electric & Manufacturing Company, and entered the general sales department of the Western Electric Company, Seattle, Washington, branch, which covers power apparatus, telephone apparatus, and general supply lines.

Mr. George B. Tripp, formerly business manager of The Central Colorado Power Company, has resigned that post to take the management of the following companies: Empire Water & Power Company, Pike's Peak Hydroelectric Company, Colorado Springs Light & Power Company, Colorado Springs Electric Company, all of Colorado Springs, Colo.

Mr. Etienne de Fodor, general manager of the Budapest General Electric Company, has been honored by the King of Hungary with the title of Privy Councillor, in recognition of meritorious work. Mr. de Fodor has been a prominent figure in the Hungarian scientific world during the last ten years, particularly in the electrical field.

Mr. T. E. Drohan, who was for a number of years superintendent of the Northern Electrical Manufacturing Company, of Madison, Wis., and recently that company's sales manager, with headquarters in Minneapolis, Minn., is now connected with the General Electric Company at Schenectady, N. Y., as general foreman of switchboard department.

Captain E. M. Sawtelle, who for seventeen years was connected with the Westinghouse companies in this country and England, has been elected president of the Planet Engineering Company, which was formed to develop a Swedish invention for thrust and radial bearings for heavy duty. He also has opened an office as consulting engineer in Temple Court Building, New York City.

Mr. A. G. Ellis has been appointed designing engineer to the Elektrizitäts Gesellschaft Alioth, Basel, Switzerland. Mr. Ellis was formerly chief assistant to Mr. H. M. Hobart, of London, with whom he collaborated in the preparation of several well-known electrical books. His duties with Mr. Hobart consisted principally in the design, standardization, inspection of, and reporting on, dynamo electric machinery of all classes, and assisting in the technical work involved in patent and legal cases.

Mr. C. G. Young, formerly of J. G. White & Company, covering sixteen years of their general experience, has opened offices at 60 Wall Street, New York City, where he will undertake engineering construction, examinations and reports, including estimated earnings for managers, owners, investors and financial syndicates in any part of the world. Having engaged to make certain important examinations and reports in the far east, Mr. Young will be in the Philippine Islands, China, Japan, and Siberia, from March until August. During Mr. Young's absence his office will be under the direction of his associate, Mr. J. N. H. Cornell.

Obituary

Clarence Edmund Gifford, Member of the Institute, died at the home of his parents 236 Fulton Street, Jamestown, N. Y., on January 23, 1909, after several years of enfeebled health. He was born at Jamestown, N. Y., April 18, 1853, son of Walter C. and Eliza C. (Robertson) Gifford. His preliminary education was received at Jamestown high school. Having an ambition for a professional career, he took the course in civil engineering at Cornell University, graduating from that institution in 1876. For the next two years he engaged in civil engineering. His interest then being aroused by the possibilities of the electrical field, then developing, he directed his energies to telephone engineering. In 1888 he turned his attention to the broader field of lighting and power engineering, to which he devoted himself for the succeeding 15 years. He became an Associate of the Institute May 16, 1893, and was transferred to the grade of Member on February 21, 1894. For four years he was electrical engineer for the Buffalo Railway Company, and for one year professor of electrical engineering in Caton's Business College. For the last four years he was special "trouble" expert in the Buffalo office of the General Electric Company, during which period he also engaged in an independent business as consulting and supervising electrical engineer. He was a contributor to the Transactions in the earlier days of the Institute, and up to the time of his death was active in its interests. His wife survives him.

American Society of Hungarian Engineers and Architects

A number of Hungarian engineers and architects pursuing their professions in this country have organized a society called the American Society of Hungarian Engineers and Architects. The society has two objects: first, to bring in closer touch engineers and architects of Hungarian extraction, living in this country, and to give moral support and information to newcomers; secondly, to encourage the exchange of engineering, technical, and industrial information between the technical men of Hungary and of the United States, and to foster technical societies, sciences and industries.

The society will hold monthly meetings where papers will be read and discussed. The membership consists of mechanical, electrical and civil engineers, chemists, architects and craftsmen. The officers of the new society are: president, A. Henry Pikler; vice-president, Karoly Z. Horvay; secretary, Zoltan de Nemeth; treasurer, Sandor Oesterreicher; assistant secretary, Ernest L. Mandel. The society's business address is Box No. 103, New York City.

Accessions to the Library

The following accessions have been made to the Library of the Institute since the last acknowledgement:

J. A. Roebling, An Account of the Ceremonies at the Unveiling of a Monument to his Memory. Roebling Press, 1908 (gift of John A. Roebling's Sons Company).

Special Investigation of the Fire Department by the Commissioner of Accounts, vols. I-II. New York, 1908 (gift).

Transformers for Single and Multiphase Currents, by Gisbert Kapp. Second revised and enlarged edition, London-New York, Whitaker & Co., 1908. $3.00 net (gift of The Macmillan Co.).

Stone and Webster Engineering Corporation. Announcement. Interurban Construction for Terre Haute Traction & Light Company. Boston, n.d. (gift of Stone and Webster Engineering Corporation).

Puget Sound Power Company Puyallup Plant. Boston, 1904. Taylors Falls Water Power Development. Boston, n.d.

National Conference of Standard Electric Rules, March 18, 1896. Minutes of proceedings of the 3d, 4th, 5th and 6th meetings, 1905-1908. History of the national electrical code, by C. J. H. Woodbury, 1906. Reprint (gift of C. J. H. Woodbury).

Influence of the Underwriters' Rules on Electrical Development, by C. J. H. Woodbury, 1907.

MANUFACTURE OF METALLIC ARTICLES ELECTROLYTICALLY—ELECTRO-ENGRAVING. By Dr. W. Pfanhauser. Authorized English translation by Joseph W. Richards, M.A., A.C., Ph.D. 162 pages. Illustrated. Easton, Pa.: The Chemical Publishing Company. Price, $1.25.

CONTENTS.—Chapter I.—Historical Review. II.—Baths for Copper Galvanoplasty. III.—Physical Properties of the Copper Deposit. IV.—Behavior of Copper Anodes. V.—Constants of the Bath and Calculation of the Amount of Deposit. VI.—Industrial Plants. VII.—Particular Devices for Special Purposes. Production of Uniform Deposits. VIII.—Manufacture of Metallic Powders and The Like. IX.—Manufacture of Metallic Foil. X.—Production of Wire etc. XI.—Manufacture of Bodies of Large Size. XII.—Manufacture of Parabolic Mirrors. XIII.—Manufacture of Tubes. XIV.—Electrolytic Etching. XV.—Electrolytic Engraving. Appendix.

THE ELECTRIC FURNACE. By Henri Moissan. Authorized translation by Victor Lehner, Ph.D. Illustrated. 302 pages. Easton, Pa.: The Chemical Publishing Company. 1904. Price, $2.50.

CONTENTS.—Chapter I.—Description of the Different Models of Electric Furnaces. II.—Various Modifications of Carbon. III.—Preparation of Some Simple Substances in the Electric Furnace. IV.—Carbides, Silicides, Borides, Phosphides, Arsenides, and Sulphides.

Alternate Current Engineering, by E. B. Raymond. Edition 3. New York, Van Nostrand Company, 1907. $2.50 net.

American Electric Railway Traction, by A. B. Herrick and E. C. Boynton. New York, McGraw Publishing Co., 1907 (gift of publishers).

American Street Railway Investments, 1908. Vol. xv. New York, McGraw Publishing Company, 1908, (gift of publishers).

Annual Report of the Board of Regents of the Smithsonian Institution, 1907. Washington, U. S. Government, 1908, (gift).

Annual Report of the Interstate Commerce Commission. 22d. Washington, U. S. Government, 1909, (exchange).

Artificial Lines for Continuous Currents in the Steady State, by A. E. Kennelly. n.p: n.d. (gift of author).

British State Telegraphs, by H. R. Meyer. New York, Macmillan Company, 1907. $1.50 net.

Bulletin of Lewis Institute, Oct. 1908. Chicago, Inst., 1908, (gift of Lewis Institute).

Book Review Digests, Vol. iv. Nos. 10, 12; Vol. 5, No. 1. Minneapolis, H. M. Wilson Company, 1908–'09, (gift of Mr. Caldwell).

Chemistry of Commerce, by R. K. Duncan. New York, Harper & Brothers, 1907. $2.00 net.

Construction of Dynamos, by Tyson Sewell. New York, Van Nostrand Co., 1907. $3.00 net.

Continuous Current Engineering. By Alfred Hay, New York, Van Nostrand Company, 1907. $2.50.

Corporation Accounting and Auditing. A Practical Treatise on Higher Accounting, by D. A. Keister. Edition 12. Cleveland, Burrows Brothers Company, 1907. $4.00.

Deductions from the Records of Running in the Last Olympiad, by A. E. Kennelly. n.p: n.d. (gift of author).

Development and Electrical Distribution of Water Power. By Lamar Lyndon. New York, J. Wiley & Sons, 1908. $3.00 net.

Dynamo, Motor & Switchboard Circuits. W. R. Bowker. Edition 2, New York. Van Nostrand Co., 1908, (gift of publishers). $2.50 net.

Economics of Railroad Construction, by W. L. Webb, New York, J. Wiley & Sons, 1907. $2.50.

The Electric Furnace in Iron and Steel Production, by J. B. Kershaw. New York, Van Nostrand Company, 1908. $3.00 net.

Electric Furnaces. By W. Borchers. Translated by H. G. Solomon. London, Longmans, Green & Co. 1908. $2.50 net.

Electric Power and Traction. By F. H. Davis. New York, Van Nostrand Company, 1907. $2.00

Electric Railway Accounting, by W. B. Brockway. New York, McGraw Publishing Co., 1906, (gift of publishers). $1.25 net.

Electric Railway and Lighting Properties, 1909. Boston, Stone & Webster, 1909, (gift of publishers).

Electric Railways. By S. W. Ashe. Vol. 2. New York, Van Nostrand Company, 1907. $2.50 net.

Electric Tramways, by W. R. Bowker. London, E. & F. N. Spon. 1903. $2.50 net.

The Electrician Primers. 3 vols. in 1. London, Electrician Pub. Co., 1906. $4.00.

Elementary Manual of Radiotelegraphy and Radiotelephony. By J. A. Fleming. London, Longmans, Green & Co., 1908. $2.00 net.

Elements of Electric Traction. By L. U. Gant. New York, Van Nostrand Company, 1907. $2.50 net.

Engineering and Electric Traction Pocket Book. London, Engineering, 1906. $5.00 net.

Finances of Gas and Electric Light and Power Enterprises. By W.D.Marks. Edition 4. New York, 1907. $4.00

Fortschritte auf dem Gebiete der Elektrischen Fernbahnen, von O. C. Roedder. Wiesbaden, C. W. Kriedels, 1909. (gift of author).

CONTENTS.—1.—Einleitung; 2. Vergleich Zwischen Dampf und Elektrizität als Betriebskraft für Bahnen. (A)—Die Vorteile des Dampfbetriebes. (B)—Die Nachteile des Dampfbetriebes. (C)—Die Vorteile des Elektrischen

Betriebes. (D)—Die Nachteile des elektrischen Betriebes. (E)—Die Rentabilität des elektrischen Betriebes. 3.—Zugswiderstand und Kraftverbrauch. 4.—Die bisherigen Anwendungen des electrischen Betriebes auf Hauptbahnen. 5.—Einteilung der elektrischen Bahnen; (B)—Nachihrer Stromart. Part II.—Die hauptsächlichen Bahnsysteme. I.—Gleichstrombahnen mit mittlerer und höherer Spannung. II.—Gleichstrombahnen mit Drehstromübertragung. III.—Das Drehstrom-Bahnsystem. IV.—Das Einphasenstrom Bahnsystem. (1)—Die Einphasenstrom-Bahnmotoren im allgemeinen. (2)—Die Einphasenstrom-Bahnmotoren im einzelnen. (C)—Der Wechselstrom-Serienmotor. (D)—Der Repulsions-motor. (E)—Der Repulsions-Serienmotor oder Serienmotor. 3.—Die kompehsierte Betrieb-Seinrichtungen und das Betriebssystem. (A)—Die Streckeneinrichtung und Kraftübertragung. (B)—Die Betriebseinrichtungen der Lokomotiven und Motorwagen. Part III. 1.—Zusammenfassender Überblick über die vier hauptsächlichen Bahnsysteme. 2.—Die Aussichten des elektrischen Bahnbetriebes in verschiedenen Ländern. Part IV.—Tabellarische Zusammenstellung der Angaben vcn 77 der wichtigeren elektrischen Bahnen Verzeichnis der in den Tabellen auf geführten Bahnen.

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Harper's Electricity Book for Boys. By J. H. Adams. New York, Harper & Brothers, 1907. $1.75.

Harper's How to Understand Electrical Work. By W. H. Onken and others. New York, Harper & Brothers, 1908. $1.75.

Heat Energy and Fuels. Pyrometry, Combustion, Analysis of Fuels and Manufacture of Charcoal, Coke and Fuel Gases, by Hanns von Jüptner. Translated by Oskar Nagel. New York, McGraw Publishing Company, 1908, (gift of publishers).

Contents.—Volume I.—Heat Energy and Fuels. Part I.—Heat Measurement, Combustion and Fuels. Chapter I.—The measurement of High Temperatures (Pyrometry). II.—Pyrometry (continued). III.—Pyrometry (conclusion). Optical Methods of Measuring Temperatures. IV.—Combustion Heat and Its Determination. V.—Direct Methods for Determining the Combustion Heat. VI.—Incomplete Combustion. VII.—Combustion Temperature. VIII.—Fuels (In general). IX.—Wood. X.—Fossil Solid Fuels (In general). XI.—Peat. XII.—Brown Coal (Lignite). XIII.—Bituminous and Anthracite Coals. XIV.—Artificial Solid Fuels. XV.—Charcoal. XVI.—Peat-Coat, Coke and Briquettes. XVII.—Coking Apparatus. XVIII.—Liquid Fuels. XIX.—Gaseous Fuels. XX.—Producer Gas. XXI.—Water Gas. XXII.—Dowson Gas, Blast Furnace Gas and Regenerated Combustion Gases.—XXIII.—Apparatus for the Production of Fuel Gases.

High Speed Dynamo Electric Machinery. By H. M. Hobart and A. G. Ellis. New York, J. Wiley & Sons, 1909. $6.00 net.

How to Become a Competent Motorman, by V. B. Livermore & J. R. Williams. New York, Van Nostrand Company, 1908. $1.00 net.

Humming Telephone, by A. E. Kennelly and W. L. Upson. n.p: n.d., (gift of A. E. Kennelly).

Laboratory and Factory Tests in Electrical Engineering. By G. F. Sever & Fitzhugh Townsend. Edition 2 New York, Van Nostrand Company, 1907. $2.50 net.

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List of Members of the Institution of Civil Engineers, January, 1909. London, Institution, 1909, (exchange).

Long Distance Electric Power Transmission. By R. U. Hutchinson. Edition 2. New York, Van Nostrand Company, 1908. $2.50 net.

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Motorman and His Duties. By Ludwig Gutmann. Edition 6. Chicago, Wilson Company, 1907. (gift of McGraw Publishing Company). $1.50 net.

Municipal Monopolies, by E. W. Bemis. New York, T. Y. Crowell & Company, 1899. $2.00.

New Physics and its Evolution. By Lucien Poincaré. New York, Appleton & Co., 1908. $1.75 net

Permanent Way for Tramway and Street Railways, by T. Arnall. London, Publishers of Railway Engineer, 1905. $5.00 net.

Peter Short, Printer, and his Marks, by. S. P. Thompson. London, Blades, East & Blades, 1898, gift of T. C. Martin).

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Practical Calculation of Transmission Lines, by L. W. Rosenthal. New York, McGraw Publishing Company, 1909, (gift of publishers).

Prevention of Accidents, by F. W. Johnson. New York, McGraw Publishing Company, 1907, (gift of publishers).

Public Ownership, by H. R. Meyer. New York, Macmillan Company, 1907. $1.50 net.

Railroad Location Surveys and Estimate, by F. Lavis. Chicago, Myron C. Clark Publishing Co., 1908. $3.00 net.

Report and Testimony of the Special Committee of the Assembly to Investigate the Desirability of Municipal Ownership of the Street and Elevated Railroads of the Various Cities of the State. Vols. 1–2. Albany, W. H. Crawford Co., 1896, (purchase).

Report in the Matter of the Purchase of the Steinway Tunnel by the City of New York as Proposed by the Interborough Rapid Transit Company. New York, 1908 (gift of Public Service Commission for the First District of the State of New York).

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Report of the Librarian of Congress, 1908. Washington, U. S. Government, 1908 (exchange).

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Vol. XXVIII **April, 1909** No. 4

April Meeting, A. I. E. E.

The April meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineers' Building, 33 West Thirty-ninth Street, New York City, on Friday, April 9, 1909, at 8 o'clock p.m. This meeting will be under the auspices of the HIGH-TENSION TRANSMISSION COMMITTEE. The following papers will be read:

"High-Voltage Transformers and Protective and Controlling Apparatus for Outdoor Installation." By Mr. K. C. Randall, engineer in charge of transformer design, Westinghouse Electric and Manufacturing Co.

"Condenser Type of Insulation for High-Tension Terminals." By Mr. A. B. Reynders, engineer with the Westinghouse Electric and Manufacturing Co.

The former deals with the design of high-voltage transformers, oil switches, and lightning-arresters for installation outdoors, thus saving the cost of a building and doing away with the expense of high-voltage wall outlets.

The latter has to do with a new development in the design of high-voltage terminals and bushings, which results in a much smaller and more reliable bushing than those which have been in use heretofore, and which lends itself readily to the construction of bushings for outdoor apparatus.

Both of these papers should be of great interest to those having to do with transmission matters. At the meeting, the high-tension terminals will be tested to 250,000 volts.

Industrial Education Meeting, April 16, 1909

A special meeting of the Institute will be held in the Engineers' Building, 33 West Thirty-ninth Street, New York City on Friday, April 16, 1909, at 8 o'clock p.m. This meeting will be under the auspices of the Educational Committee, a sub-committee of the Meetings and Papers Committee. Herman Schneider, dean of the College of Engineering of the University of Cincinnati, will present a paper entitled "Fundamental Principles of Industrial Education." [The paper is printed in this issue of the PROCEEDINGS.]

Twenty-fifth Anniversary Dinner

MARCH 11, 1909.

A dinner commemorating the twenty-fifth anniversary of the founding of the Institute was held at the Hotel Astor, New York City, on Thursday evening, March 11, 1909. About three hundred persons were present, including representatives of sixteen of the Institute's Sections and Branches. The decorations in the main dining room were presented with the compliments of The Edison companies of New York, Chicago, Brooklyn, Boston, and Philadelphia.

During the service of the dinner, President Ferguson read congratulatory telegrams from the Institution of Electrical Engineers, the Verband Deutsche Elektrotechnische, the Societe Internationale des Electriciens, Dr. Alexander Graham Bell, Mr. Thomas A. Edison, and a letter from Mr. Charles F. Brush.

After the dinner, President Ferguson gave an introductory address outlining the history of the Institute from 1884 to 1909. Among other interesting things, President Ferguson said that the Institute had increased in membership from 279 in 1885 to 6630 in 1909; that the finances of the Institute are in splendid condition; and that the administration of its affairs to-day compels an annual expenditure of approximately $80,000. President Ferguson also referred to the 835 foreign members, the Section and Branch work, the PROCEEDINGS and TRANSACTIONS, and other phases of Institute activity.

Mr. Jesse M. Smith, President of the American Society of Mechanical Engineers, extended greetings from sister engineering societies.

Professor Elihu Thomson, past-president of the Institute, responded to the toast " The Charter Members." At the conclusion of Professor Thomson's remarks, President Ferguson announced that a diploma of congratulation will shortly be presented to every living charter member of the Institute. Seven of these charter members were present at the dinner; namely, Charles L. Clarke, George A. Hamilton, C. O. Mailloux, T. Commerford Martin, Jesse M. Smith, Elihu Thomson, and Elmer A. Sperry.

Mr. Frank J. Sprague replied to the toast " The Past-Presidents." In concluding his response, on behalf of past-presidents, Messrs. Weston, Thomson, Bell, Sprague, Duncan, Crocker, Kennelly, Hering, Steinmetz, Scott, Arnold, Lieb, Wheeler, Sheldon, Stott, and Ferguson, Mr. Sprague presented a loving cup to Mr. T. Commerford Martin, senior past-president of the Institute.

" Electrical Engineering as a Profession " was the subject of a toast responded to by Dr. Alexander C. Humphreys, President of the Stevens Institute of Technology.

The dinner committee consisted of Messrs. T. C. Martin, Theodore Beran, Maurice Coster, Minor M. Davis, Horatio A. Foster, George A. Hamilton, Robert T. Lozier, William McClellan, F. A. Muschenheim, Henry W. Pope, Charles W. Price, F. A. Scheffler, E. A. Sperry, Albert Spies, Arthur Williams, George H. Guy, H. H. Barnes, Jr., Walter L. Conwell, Henry Floy.

Annual Convention

At a meeting held February 19, 1909, the Board of Directors voted to hold the next annual convention at the Hotel Frontenac, Thousand Islands, Frontenac, New York. The convention will begin Monday, June 28, 1909, and will end at a time to be announced later. A tentative list of the papers to be presented is as follows:

1. Some Considerations in Designing Heavy Capacity Fuses. By L. W. Downes.
2. A Sketch of the Theory of the Adjustable Speed Single-phase Shunt Induction Motor. By F. Creedy.
3. Vector Representation of Non-Harmonic Alternating Currents. By Bonroku Arakawa.
4. Split-Pole Converters and Storage-Battery Regulation at Gary, Indiana. By J. L. Woodbridge.
5. The Effect of Frequency upon the Cost of Alternators. By C. J. Fechheimer.
7. Two papers on high-tension transmission subjects. By R. D. Mershon.
8. The Reduction in Capacity of Induction Motors due to Unbalancing in Voltage. By S. B. Chartres and W. A. Hillebrand.
9. The Heating of Induction Motors. By Alexander M. Gray.
10. Telephone paper. By J. J. Carty.
13. Three power papers. By D. B. Rushmore.
14. Sparking-Point Distance.

15. The Resistance and Reactance of Armored Cables. By J. B. Whitehead.
17. Two educational papers. By H. H. Norris.
18. Generators for 100,000 Cycles. By E. F. Alexanderson.
19. Repulsion Motors with Variable-Speed Shunt Characteristics. By E. F. Alexanderson.

Minutes of March Meeting of the Institute

The two hundred and thirty-fifth meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers' Building, 33 West thirty-ninth street, New York, Friday, March 12, 1909. President Ferguson called the meeting to order at 8:00 p.m.

The secretary announced that at a meeting of the Board of Directors held during the afternoon, at which the following directors were present: President Louis A. Ferguson, Chicago, Ill.; Vice-presidents Calvert Townley, New Haven, Conn.; C. C. Chesney, Pittsfield, Mass.; Bancroft Gherardi, New York; W. C. L. Eglin, Philadelphia, Pa. Managers W. S. Murray, New Haven, Conn.; P. M. Lincoln, Pittsburg, Pa.; Paul Spencer, Philadelphia, Pa.; Percy H. Thomas, New York; W. G. Carlton, New York; Henry G. Stott, New York; C. W. Stone, Schenectady, N. Y., H. W. Buck, New York; Morgan Brooks Urbana, Ill.; David B. Rushmore, Schenectady, N. Y. Secretary Ralph W. Pope, New York, nominations for officers of the Institute to be elected May 18, 1909, were made as follows:

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George A. Hamilton, New York.

FOR SECRETARY.

Ralph W. Pope, New York.

The secretary announced further the election of 113 Associates as follows:

ARGABRITE, NEWTON MUNDAY, General Superintendent, Winona Railway & Light Co.; res., 110 West 7th St., Winona, Minn.

AXTELL, CLINTON JESSE, Student Engineer, General Electric Co.; res., 17 Barrett St., Schenectady, N. Y.

BAER, CARL AMBROSE, Electrical Engineer, with Robert W. Watson; res., 514 N. 3rd St., Harrisburg, Pa.

BAGLEY, FRANCIS HENRY, Engineer Apprentice, The Union Switch & Signal Co., Swissvale, Pa.

BARROLL, LEE, Student, Harvard University; res., 52 Mt. Auburn St., Cambridge, Mass.

BERNIER, CHARLES AUGUSTIN, Superintendent of Construction, Winona Ry. & Lt. Co.; res., 621 W. King St., Winona, Minn.

BLAIR, EDWARD JOHNSON, Engineer, The Metropolitan West Side Elevated Ry. Co.; res., 742 Warren Ave., Chicago, Ill.

BOMAN, CARL EMANUEL, District Foreman, The New York Telephone Co., New York City; res., 495 Washington Ave., Brooklyn, N. Y.

BOYD, FRANCIS EVANS, Electrical Engineer, Washington Water Power Co.; res., 919½ Riverside Ave., Spokane, Wash.

BOYRER, WILLIAM CHARLES, Asst. Electrical Engineer, Public Service Commission, New York City; res., 167 80th St., Brooklyn, N. Y.

BRAGDON, WILLIAM BRYANT, General Manager, S. D. Warren & Co., Westbrook, Maine.

BROWN, HARRY MORGAN, Ontario Power Co., Niagara Falls, Ontario.

BROWN, HARRY WHEELER, with D. C. & W. B. Jackson, Boston; res., 118 Brighton Ave., Allston, Mass.

Buckman, William Drayton, Erecting Engineer, Westinghouse Electric & Mfg. Co.; res., 3016 N. 15th St., Philadelphia, Pa.

Button, Arnold E., Electrical Engineer, General Electric Co., Schenectady, N. Y.

Canizal, Joaquin, Superintendent, The Porto Rico General Telephone Co., San Juan, Porto Rico.

Carr, Frank, Chief Operator, Utah Light & Railway Co., Ogden, Utah.

Carter, Emmett B., Asst. Chief Engineer, The Midvale Steel Co., Philadelphia; res., 236 Winona Ave., Germantown, Pa.

Chase, Eugene Preston, Assistant Engineer, Westinghouse Electric & Mfg. Co., Pittsburg; res., 757 North Ave., Wilkinsburg, Pa.

Chynoweth, George William, Master Mechanic, Ft. Smith Light & Traction Co.; res., 1006 N. 15th St., Ft. Smith, Ark.

Collins, Clarence Rivers, Apprentice Westinghouse Electric & Mfg. Co., Pittsburg; res., 511 Franklin Ave., Wilkinsburg, Pa.

Cooper, Albert, Draughtsman, New York Edison Co., New York City; res., 2 Raleigh Place, Brooklyn, N. Y.

Cooper, Marion Deane, Assistant Instructor in Electrical Engineering, Univ. of Wisconsin; res., 515 Frances St., Madison, Wis.

Cooper, Orville, Engineer, Fort Wayne Electric Works; res., 614 W. Creighton Ave., Fort Wayne, Ind.

Cox, John Bogle, Railway Engineering Department, General Electric Co., Schenectady, N. Y.

Craighead, James Ray, Laboratory Assistant, General Electric Co.; res., 57 Haigh Ave., Schenectady, N. Y.

Culverwell, John Alexander, Managing Director, The Central Ontario Power Co., Peterboro; res., Port Hope, Ont.

Demming, Roy Oliver, Wire Chief, The Bell Telephone Co. of Penna., Philadelphia; res., 353 E. Chelten Ave., Germantown, Pa.

Dunn, Andrew Paul, Contract Dept. Minneapolis Gen. Elec. Co.; res., 1654 Capitol Ave., St. Paul, Minn.

Ellicott, W. J., Chief Electrician, Cananea Consolidated Copper Co., Cananea, Sonora, Mex.

English, Earl Forman, Testing Engineer, The Public Service Railway Co. of N. J.; res., 73 Crescent Ave., Jersey City, N. J.

Evarts, Harold Chester, Cable Engineer, Nebraska Telephone Co., Omaha Neb.

Fair, Richard Harvey, Superintendent of Construction, Nebraska Telephone Co., Omaha, Nebraska.

Farrar, John Charles, Electrical Engineer, Cananea, Yaqui River & Pacific Railroad, Empalme, Sonora, Mexico.

Filkins, Barent Latham, The Ontario Power Co., Niagara Falls, Ont.; res., Buffalo, N. Y.

Ford, Leroy Stearns. Electrical Engineer, with Albert B. Herrick, New York City; res., 492 Classon Ave., Brooklyn, N. Y.

Ford, Ralph Henry, Student, University of Wisconsin; res., 214 State St., Madison, Wis.

Gagen, James M., Electrical Draughtsman, New York Edison Co.; res., 922 6th Ave., New York, N. Y.

Gawthrop, Ernest, Superintendent, Diamond National Bank Building Pittsburg; res., Wilkinsburg, Pa.

Gay, Harold, Inspector of Electrical Apparatus for L. B. Stillwell; res., Edison Hotel, Schenectady, N. Y.

Geib, William V., Salesman, Westinghouse Electric & Mfg. Co.; res., 246 W. Lanvale St., Baltimore, Md.

Gibbs, Jesse B., Transformer Designer, Westinghouse Electric & Mfg. Co., Pittsburg; res., 852 Rebecca Ave., Wilkinsburg, Pa.

Groce, George Henry, Superintendent of Telegraph & Signals, The Illinois Central R.R. Co., Chicago, Ill.

Hall, William H., Electrical Inspector, Phila. Fire Underwriters Association, res., 5243 Addison St., Philadelphia, Pa.

Hammond, John F., Manager, Electrical Dept., The S. S. White Dental Mfg. Co., Prince Bay, S. I., New York.

Handy, William Winder, Electrical Engineer, Annapolis Short Line Railway; res., University Club, Baltimore, Md.

Hatch, Bert Edward, Electrical Engineer, The American Thread Co.; res., 56 Park St., Willimantic, Conn.

Hays, Donald Symington, Inspector of Transmission Line Construction, Viele, Blackwell & Buck, 49 Wall Street. N. Y. City.

Henry, Edward Newton, Sub-station Foreman, N. Y. C. & H. R. R.R.; res., 303 West 51st St., New York, N. Y.

Hunter, Thomas Benton, Resident Engineer, Pacific Improvement Co., Monterey, Cal.

Huntington, Richard Joseph, Selling Agent, Otis Elevator Co., 218 East Fourth St., Los Angeles, Cal.

Jones, John Paul, Superintendent, Citizens Gas & Electric Co., Cedar Falls, Iowa.

Kelly, Alfred S., Superintendent, The Nebraska Telephone Co., Omaha, Neb.

Kennedy, Walter Critchlow, Electrical Engineer, The Cutler-Hammer Mfg. Co.; res., 1420 Grand Ave., Flat No. 7, Milwaukee, Wis.

Kirby, Omer, Engineer, Automatic Electric Company; res., 34 Throop Street, Chicago, Ill.

Knopp, Otto A., Superintendent Meter Dept., Pacific Gas & Electric Co.; res., 864 Milton St., Oakland, Cal.

Knowlen, John Furniss, Superintendent and Master Mechanic, North Alabama Traction Co., New Decatur, Ala.

Laird, Guy Morgan, Apprentice Engineer, Westinghouse Electric & Mfg. Co.; res., 7920 Tioga St., Pittsburg, Pa.

Laughlin, Henry Hughart, Electrical Engineer, Jones & Laughlin Steel Co.; res., 5023 Bayard St., Pittsburg, Pa.

Lehman, Edwin Leander, Testing Table Operator, Bell Telephone Co. of Penna., Philadelphia; res., 811 No. 4th St., Camden, N. J.

Lewis, Harry Byron, Sub-station Operator, California Gas & Electric Co., Redwood City, Cal.

Louis, Henry Charles, Assistant, Baltimore & Ohio Railroad; res., 2322 Callow Ave., Baltimore, Md.

Lubbert, George Louis, Machinist, General Electric Co.; res., 1618 Turk St., San Francisco, Cal.

MacGuinness, Robert B., Electrical Dept., Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N. Y.

Makino, Kengo, Student, Cornell University; res., 112 Ferris Place, Ithaca, N. Y.

Malan, Henry Ernest de Merindol, Testing Engineer, Canadian Westinghouse Co.; res., 313 Main St., W., Hamilton, Ont.

Maris, Hoadley Boyd, Chief Electrician, Camp Bird, Limited, Ouray, Colorado.

May, Alexander George Henry, Electrical Engineer Simla Hydro-electric Scheme, Basantpur. via Mashobra, Simla, India.

May, Oscar John, Watch Engineer, Sanitary District of Chicago; res., Lockport, Ill.

McWethy, William Ernest, Operating Foreman, Union Construction Co., Vallecito, Cal.

Merwin, William Clate, Asst. Chief Electrician, Republic Iron & Steel Co.; res., 32 N. Center St., Youngstown, Ohio.

Morse, Augustus Lotrhop, Superintendent of Electric Light & Power, American Woolen Co., Assabet Mills, Maynard, Mass.

Morsman, Frank S., Assistant Engineer, Nebraska Telephone Co., Omaha, Neb.

Mortensen, Soren Hansen, Electrical Engineer, Allis-Chalmers Co., West Allis, Wis.

Nelson, Edwin Eugene, Electrical Engineer, Northern Texas Traction Co., Fort Worth, Texas.

Nesbitt, Robert Maitland, Electrical Inspector, Phila. Fire Underwriters Assn.; res., 5253 Addison St., Philadelphia, Pa.

Onken, William Henry, Jr., Associate Editor, Electrical World, New York City; res., 248 Carroll St., Brooklyn, N. Y.

Orr, Samuel Marshall, Jr., Superintendent, Abbeville Water & Electric Plant, Abbeville, S. C.

Paddock, Orville Wood, McCall Ferry Power Co., 60 Wall St.; res., 15 East 11th St., New York City.

Palecek, James Frank, Commercial Engineer, General Electric Co.; res., 22 Gillespie St., Schenectady, N. Y.

Parrott, Reginald George, Engineering Apprentice, The British Westinghouse Electric & Mfg. Co., Trafford Park, Manchester, Eng.

Pattberg, George, Electrician, C. W. Hunt & Co., West New Brighton; res., 96 Grove St., New York, N. Y.

Payne, Harold Gould, Engineer, with D. C. & W. B. Jackson, 508 Commercial National Bank Bldg., Chicago, Ill.

Peaslee, Alexander Sanky Latty, Engineer Salesman, Canadian Westinghouse Co., Traders Bank Bldg., Toronto, Ont.

Peck, Bertine Hila, Electrical Engineer, with D. C. & W. B. Jackson; res., 2631 N. Robey St., Chicago, Ill.

Plumb, William Hall, Chief Electrician, American Steel & Wire Company; res., 615 Clinton St., Joliet, Ill.

Popp, Lee W., Student, University of Wisconsin; res., 524 N. Henry St., Madison, Wis.

Raggio, Victor Emanuel, Manager, The Wesco Supply Co., Fort Worth, Texas.

Rhine, Morris, Salesman, General Electric Co.; res., 1086 Fulton St., San Francisco, Cal.

Rhodes, Thomas Bartley, Manager, The United Electric Light & Power Co., 1170 Broadway, New York, N. Y.

Ridge, Samuel Bertrand, General Plant Inspector, Central District & Printing Tel. Co., Pittsburg, Pa.

Rochester, Thomas Walter, Electrical Engineer, Dept. of Water Supply, Gas & Electricity, New York, N. Y.

Rogers, Frank T., Electrician, The Great Northern Power Co., Fon Du Lac, Minn.

Rollins, Edwin Butler, Instructor in Electrical Engineering, Tufts College, Tufts College Station, Mass.

Rolph, Thomas Willett, Illuminating Engineer, The Holophane Co.; res., 15 East 32nd St., New York, N. Y.

Savage, Willis Crawford, Test Man, General Electric Co.; res., 112 Park Place, Schenectady, N. Y.

Schley, George Bigelow, Assistant Attorney Elec. Patent Dept., Allis-Chalmers Co., Milwaukee, Wis.

Schmidt, Sigurd Hjort, Special Student, Columbia University, New York City; res., 166 High St., Perth Amboy, N. J.

Scott, Ralph, Scott Electrical Co., 58 Nassau St., Newark; res., 215 Grafton Ave., Forest Hill, N. J.

Serus, Elmer Bonnell, Draughtsman, Wilkes Barre Gas & Electric Co.; res., 96 W. Ross St., Wilkes Barre, Pa.

Simpson, James Albert, Aerial and Underground Engineer, The New York & New Jersey Telephone Co., Newark, N. J.

Sparks Harry Holmes, Electrical Engineer, War Dept., United States Government, Junction City, Kansas.

Stienbach, Edward Sargent, Assistant to the Chief Engineer, Kinsman Block System Co., 50 Church St., New York, N. Y.

Stone, Porter Edwards, Assistant in Laboratory, Lewis Institute; res., 754 Washington Boulevard, Chicago, Ill.

Sugg, Charles Rountree, Electrical Engineer, Atlantic Coast Line Railroad Co., Wilmington, N. C.

Talbott, Charles, Salesman, Westinghouse Electric & Mfg. Co.; res., 362 Dearborn Ave., Chicago, Ill.

Taylor, Verne Elwood, Switchboard Operator, The N. Y. N. H. & H. R.R., Cos Cob Station, res., 3 Willow Court, Stamford, Conn.

TEFFEAN, GEORGE W., Superintendent, United Electric Construction Co.; res., 5905 Tacony St., Philadelphia, Pa.

TOTTEN, ARTHUR IRVING, Railroad Shop Specialist, General Electric Co., Schenectady, N. Y.

WALKER, GLENN BRUBAKER, Research Engg. Dept., Westinghouse E. & M. Co., Pittsburg; res., 294 Bruttian Ave., Benton Harbor, Mich.

WEST, JUDSON RAY, Assistant Engineer, Engineering Dept., City of Seattle, Seattle, Wash.

WHEELOCK, RAYMOND B., Chief Clerk to Superintendent, Nebraska Telephone Co., Omaha, Neb.

WRIGHT, CHARLES ALLEN, Instructor in Electrical Engineering, Harvard University; res., 64 Oxford St., Cambridge, Mass.

The secretary announced further that the following Associates were transferred to the grade of Member:

WALTER REICHEL, Professor, Department of Applied Electricity, University of Berlin, Germany.

HENRY WATERMAN PECK, Assistant Electrical Engineer, Rochester Railway & Light Company, Rochester, N. Y.

GEORGE EDWIN CLAFLIN, Electrical Engineer, United Electric Securities Company, 47 Ames Building, Boston, Mass.

BRADLEY T. MCCORMICK, Chief Electrical Engineer, Allis-Chalmers-Bullock, Ltd., Montreal, P. Q.

PAUL SPENCER, Inspector of Electric Plants, United Gas Improvement Co., Philadelphia, Pa.

ROBERT HALSEY HENDERSON, Manager of Works, Westinghouse Lamp Works Bloomfield, N. J.

Mr. Barton R. Shover, electrical engineer of the Indiana Steel Company, of Gary, Indiana, then presented a paper entitled "The Industrial Application of the Electric Motor, as Illustrated in the Gary Plant of the Indiana Steel Company." The paper was illustrated by lantern slides. The paper was discussed by Messrs. B. A. Behrend, Gano Dunn, D. B. Rushmore, W. T. Dean, Robert Hull, Brent Wiley, L. A. Ferguson, and B. R. Shover.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before May 1, 1909.

8398 Dansie, F., Necaxa, Puebla, Mex.
8399 Davis, E. R., Los Angeles, Cal.
8400 Ferris, J. W., Union City, Ind.
8401 Gooding, H. C., Toronto, Ont.
8402 Hall, Henry R., Schaghticoke, N.Y.
8403 Kylie, H. R., Charlestown, Mass.
8404 Marshall, S. M., Johnstown, Pa.
8405 Schwarz, P. G., New Bremen, O.
8406 Searing, E. De F., Portland, Ore.
8407 Bodler, Oscar W., Rochester, N. Y.
8408 Peirce, H. B., Cambridge, Mass.
8409 Pouch, Oscar G., Yonkers, N. Y.
8410 Skelley, F. V., Morton Park, Ill.
8411 Dyche, H. E., Pittsburg, Pa.
8412 Holcomb, A. M., Ithaca, N. Y.
8413 Boughton, J. H., St. Louis, Mo.
8414 Carroll, R. S., Portland, Ore.
8415 Costerisan, M. R., Los Angeles, Cal
8416 Durkee, B. S., Portland, Ore.
8417 Hutton, C. H., Hamilton, Ont.
8418 King, Wm. F., New York, N. Y.
8419 Kingsbury, N. L., Portland, Ore.
8420 Kirkland, H. A., Portland, Ore.
8421 Maupin, S. T., Madison, Ga.
8422 Mitchell, R. M., Fort Monroe, Va.
8423 Monk, H. W., Raleigh, N. C.
8424 Nash, F. M., Provo, Utah.
8425 Nock, G. P., Portland, Ore.
8426 Owens, C. C., New York, N. Y.
8427 Thompson, J. C., Lemoyne, Pa.
8428 Waugh, L. R., Brooklyn, N. Y.
8429 Maughan, Allan, Seattle, Wash.
8430 Middleton, W. I., Boston, Mass.
8431 Mathews, R. B., Seattle, Wash.
8432 Miller, C. W., Rochester, N. Y.

8433 Mock, J. C., Detroit, Mich.
8434 Somers, James, Harwood Mines, Pa.
8435 Thompson, G. W., Montreal, Can.
8436 Bullard, Benj., Canyon Ferry, Mont.
8437 Fullerton, D. P., San Francisco, Cal.
8438 Glauber, Moses M., St. Louis, Mo.
8439 Parrish, J., Leavenworth, Kansas.
8440 Rutledge, G. E., San Francisco, Cal.
8441 Bosard, B. V., Evansville, Ind.
8442 McAfee, W. C., Atlanta, Ga.
8443 Nicholls, H. G., Toronto, Ont.
8444 Trammell, W. H., Belton, S. C.
8445 Blakeman, S. R., Lafayette, Ind.
8446 Convill, J. O., Salt Lake City, Utah
8447 Merriell, F. C., Colorado Spgs., Colo.
8448 Browne, R. C., Salem, Mass.
8449 Cornelius, M., Pittsburg, Pa.
8450 Dales, J. S., Jr., Franklin, Ind.
8451 Hateley, J. J. C., St. Louis, Mo.
8452 Little, A. P., Syracuse, N. Y.
8453 Manson, G. K., Boston, Mass.
8454 Perry, Wm. J., Niagara Falls, Ont.
8455 Schaefer, C. J. H., Mysore, India.
8456 Starmer, F. A., San Jose, Cal.
8457 Stroh, H. N. Jr., Ossining, N. Y.
8458 Wharton, J. B., Wilkes-Barre, Pa.
8459 Neu, S. S., Ampere, N. J.
8460 Stahl, Axel J., Stockholm, Swe.
8461 Thornton, E. B., La Crosse, Wis.
8462 Waller, B., Minneapolis, Minn.
8463 Norman, R. C., Merrielan, Wis.
8464 Pierce, M. S., Toronto, Ont.
8465 Procter, John R., Fort Monroe, Va.
8466 Riedell, P. W., Schenectady, N. Y.
8467 Stevenson, R. E., Oakland, Cal.
8468 Guckel, C. H., Brooklyn, N. Y.
8469 Kammerer, C. F., Baltimore, Md.
8470 Newton, O. S., Mansfield, Ohio.
8471 Warren, C. H., San Francisco, Cal.
8472 Wilson, G. A., Philadelphia, Pa.
8473 Harding, W. R., London, E.C., Eng.
8474 Ballard, W. P., Exeter, Cal.
8475 Burns, J. F., Schenectady, N. Y.
8476 Birdler, T. M., Atlanta, Ga.
8477 Griffiths, M. R., Toronto, Can.
8478 Leonard, A. W., Minneapolis, Minn
8479 Minns, R. H., Pittsburg, Pa.
8480 Wilkinson, C.D., Minneapolis, Minn.
8481 Martin, F. P., Cleveland, Ohio.
8482 Goldman, J. E., Philadelphia, Pa.
8483 Morgan, R. C., Philadelphia, Pa.
8484 Rover, A. B., Binghamton, N. Y.
8485 Weber Eugene, Denver, Colo.
8486 Decker, Geo. E., Los Angeles, Cal.
8487 Harding, Wm. A., Los Angeles, Cal.
8488 Morgan, D. D., Los Angeles, Cal.
8489 Noodill, H. B., Los Angeles, Cal.
8490 Nye, A. W., Los Angeles, Cal.
8491 Pearson, B. F., Los Angeles, Cal.
8492 Angus, D. J., East Lansing, Mich.
8493 Doll, C. E., New York, N. Y.
8494 Mitchell, G. W., Portland, Ore.
8495 Wagner, R. E., Peterboro, Ont.
8496 Derge, F. J., Denver, Colo.
8497 Houghton, H. F., Cleveland, O.
8498 Hume, Fred, Michigan City, Ind.
8499 Kenyon, R. S., New Orleans, La.
8500 Sykes, W., Pittsburg, Pa.
8501 West, O. H., Anderson, Ind.
8502 Wurth, Wm., Chicago, Ill.
8503 Alexander, J.L., St.Croix Falls, Wis.
8504 Cassity, L. H., Decatur, Ill.
8505 Crookes, S. I., Auckland, New Zealand.
8506 Sheely, J. H., Brooklyn, N. Y.
8507 Shoemaker, R. S., Monessen, Pa.
8508 Armstrong, F. W., El Oro, Mex.
8509 Carlin, Wm. A., Washington, D. C.
8510 Eskew, W. E., Electra, Cal.
8511 Johnson, H. S., Buffalo, N. Y.
8512 Rhodes, T. A., Jr., New York, N. Y.
8513 Rodgers, J. F., Pittsburg, Pa.
8514 Barker, C. J., Porto Bello, C. Z.
8515 Gawtry, L. B., New York, N. Y.
8516 Haring, J. Y., Sioux City, Iowa.
8517 Reimer, Adolph, Jr., Brooklyn, N. Y.
8518 Wilson, E. W., Oakland, Cal.
8519 Corbin, M. M., Philadelphia, Pa.
8520 Israel, J. D., Philadelphia, Pa.
8521 Woodbury, E. E., Pittsburg, Pa.
8522 Allison, P. L., Peterborough, Ont.
8523 Carleton, R. A., Newton, Mass.
8524 McDougall, D. H., Toronto, Ont.
8525 Weber, F. D., Portland, Ore.
8526 Emerson, R. W., Cleveland, Ohio.
8527 Johnson, C. E., Los Angeles, Cal.
8528 Loder, F. F., Medford, Oregon.
8529 Long, J. M., Los Angeles, Cal.
8530 Mitchell, P. H., Toronto, Ont.
8531 Fales, H. M., Jr., New York, N. Y.
8532 Searle, R. M., Rochester, N. Y.
8533 Cloud, F. W., Pittsburg, Pa.
8534 Grant, L. S., Montreal, Canada.
8535 Luther, B. S., Newburyport, Mass.
8536 Braden. N. S., Hamilton, Ont.
8537 Elsom, T. H., Spokane, Wash.

8538 Hennecke, E. V., Bucyrus, Ohio.
8539 Phelps, H. S., Marble, Colo.
8540 Blundin, L. C., Philadelphia, Pa.
8541 Brooks, F. W., Philadelphia, Pa.
8542 Brown, W.T., Jr., Philadelphia, Pa.
8543 Dillard, J. B., Washington, D. C.
8544 Ganong, W. K., Orono, Maine.
8545 Hollingsworth, Wm., Phila., Pa.
8546 Hooker, D. C., Farmington, Conn.
8547 MacWilliams, J. F., Lansford, Pa.
8548 McLaughlin, J. F., Phila., Pa.
8549 Steele, W. I., Farmington, Mo.

Total, 152.

Applications for Transfer

Recommended for transfer by the Board of Examiners March 12, 1909. Any objection to these transfers should be filed at once with the secretary.

CHARLES GEORGE ADSIT, Consulting Electrical and Mechanical Engineer, Magdalena, Sonora, Mexico.

EDMUND MUNROE SAWTELLE, Consulting Engineer, and President Planet Engineering Co., Temple Court, New York.

Alaska-Yukon-Pacific Exposition

In anticipation of visits from many engineers throughout the country to the Alaska-Yukon-Pacific Exposition, the Seattle Section is coöperating with the Pacific Coast engineering societies as well as national organizations with a view to making one of the features of the exposition a general engineers' convention such as was held at Portland Oregon, in 1908. Joint committees have been appointed to formulate a plan of entertainment of visiting engineers, and preparations are now going forward to establish a general headquarters and bureau of information for their benefit, in the new and commodious rooms of the Seattle Section at the Chamber of Commerce, Central Building, Seattle. The railroad companies are making special rates from all points in the United States to Seattle and the summer Alaska trip.

Recent Developments in Transforming Apparatus*

In this paper an attempt will be made to outline as concisely as possible a few of the developments in transforming devices that have taken place during the last year. Some of these we are perhaps already familiar with, while others may present new ideas or well known principles applied in new ways. At all events, it is hoped that a brief review of the work may prove of some interest. Naturally the first subject which suggests itself is the one which deals with some of the largest apparatus built, so that a short review will be given of the steps which have led up to the later designs, with special reference to features which make the building of large transformers possible.

The forced-oil transformer. When oil first came into general use a few years ago for the purpose of insulating and cooling, transformers were comparatively small in size and the surface of coils and core was comparatively large in proportion to the quantity of heat to be dissipated. The natural circulation of the oil, therefore, due to the difference in heat at the top and bottom of containing tank, was sufficient to maintain the proper temperature. As the size of transforming apparatus increased, it became necessary to provide additional tank surface in the shape of corrugations or veins in order not only to radiate the increased amount of heat, but also to maintain a difference in temperature between the upper and lower portions of the oil, so as to cause its more rapid circulation. After a time, even this arrangement proved inadequate and it became necessary to resort to other means. This time an internal water cooling-coil was introduced and by its means a still further difference in heat potential was created, resulting naturally in a more rapid transfer of heat. In all these designs it should be noted that the natural circulation of oil is relied upon to convey heat from the coils and interior of the transformer to the outer cooling surface..

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* Paper read by H. W. Tobey before the Schenectady Section of the American Institute of Electrical Engineers, Thursday, December 18 1908.

The size of units continuing to increase, the amount of heat to be dissipated became greater, and the seat of its generation more and more remote from the cooling surfaces. The next step, then, was to assist the natural circulation of oil, resulting in what we call to-day the forced-oil type of transformer. This provided a means of rapidly transferring heat from the inner portion of core and coils to the outside where it could be readily taken care of.

Several advantages resulted. With the increased circulation all parts of the coils and core were maintained at a more uniform temperature, those at the top being little warmer than those at the bottom. This feature also made it possible to transfer a greater quantity of heat to the oil than before, and, further, heat pockets were eliminated. As a result of these advantages, the radiation constants could be increased and the amount of active material proportionately decreased. Thus it has been possible with this type of construction to reduce considerably the cost of the transformer, provided the size of the unit were large enough and the voltage not too great in proportion to the kilowatt rating. In regard to this point, more will be said later. On the other hand, additional auxiliary apparatus is required in the way of pumps, coolers, etc., which tend somewhat to offset this saving; in fact it does offset it where the combined capacity of the individual units is much less than 5000 kw. For equipments larger than this, it is always well to consider the forced-oil design.

Mention has already been made of the size of the unit and the voltage as affecting the adoption of forced oil circulation. The reasons are apparent from the following. For transformers of comparatively small capacities and high voltages, the size of the conductor and dimension of the coils must be such as to give the required mechanical safety and ruggedness. In other words, the conductor and coils are made as small as safety will allow. It is manifest, then, that nothing would be accomplished by resorting to mechanical circulation. With these considerations in mind, it is usually found inadvisable to make this type in sizes of less than 1200 to 1500 kw.

In equipments already designed and built the practice has been to employ two complete sets of cooling and circulating apparatus, one to be used as a spare unit in case of failure of the other. Each consists of a pump for circulating the coil, a surface condenser or cooler, and a pump for circulating the water—all of these being suitably connected to the transformer by means of delivery and return pipes.

This type of transformer is similar to the standard water-cooled type without the cooling coil. Provision is made, however, for the uniform distribution of incoming oil by enclosing the lower part of the coils with a metal box fitted with baffle plates. Oil is led into this chamber by means of a vertical pipe passing down through the cover. The outlet is placed somewhat above the tops of the coils and considerably below the surface of the oil, so that there will be no danger of uncovering the former and so that no air will be drawn into the system.

For large plants this arrangement of a cooling system common to a number of transformers is working admirably. There are now installed and in successful operation in various parts of the United States more than 102,000 kw. of 60-cycle, 60,000-volt, forced-oil transformers.

In some plants where the conditions are suitable, it has been thought advisable to adopt individual coolers and separate oil-circulating pumps and motors. In one installation consisting of six 5000-kw. units the waters in the tailrace pass in close proximity to the transformers; this feature was taken advantage of by specifying individual coolers to be placed in the tail race where the circulating oil can be efficiently cooled without resorting to any auxiliary water-circulating devices. Each unit will also be provided with its own oil pump and motor, making it entirely separate from the others. With this arrangement any trouble occurring in one transformer, due perhaps to moisture or breakdown, cannot be communicated to other units in the same equipment; this contingency is not so easy to provide against in the design previously mentioned. Moreover, any transformer can be removed or a new one installed without in the least interfering with the others.

There are some plants, however, where conditions preclude the use of individual condensers or coolers; certain steam-power plants, for example, or water-power plants where the tail-race is remote from the transformer house. To provide for such conditions a new type of forced-oil apparatus has been developed which is entirely self-contained. Even the external cooler is done away with, so that the equipment is still more flexible than the one in the installation referred to above. In this apparatus the cooling coil is placed inside the tank as in the water-cooled type, except that its convolutions extend nearly to the bottom. A cylindrical or elliptical metal casing, depending upon the contour of the tank, separates this coil from the main oil chamber, with the exception of one or more openings at the bottom. By means of an individual motor and circulating pump mounted on the cover or in close proximity to the transformer the oil is pumped out at the top of the central chamber and into the space inclosing the cooling coil. The static head caused by the resulting difference in level thus greatly increases the natural oil circulation through the coils and core. The result is an outfit of extremely simple design, which, on account of its self-contained features, is as flexible as one of the ordinary water-cooled type. It embodies the same features as the forced-oil equipments already built and at the same time prevents troubles in one unit from spreading to the others. An equipment consisting of two 3000 kw. transformers of this description is soon to be put in service.

Before passing from this subject, it might be well to add a word or two as to the actual temperatures of oil and water, and to compare the operation of the forced-oil type with that of the ordinary water-cooled or oil-cooled design. It is customary in forced-oil apparatus to circulate sufficient water to carry away the heat with a rise in temperature of the water of approximately 10 degrees. If the temperature of the incoming water then is 15 degrees, that of the outgoing will be 25 degrees. This usually requires about one-third of a gallon per minute per kilowatt loss in the transformer. Approximately the same temperature rise is allowed in the oil, so that the greatest difference in oil-temperature between the bottom and top of the tank is not far from 10 degrees. The specific heat of oil is a little less than one-half that of water, therefore its theoretical rate of flow would be approximately double. Practice bears this out, except that in some cases it is found advisable to increase the flow of oil to three or three and one-half times that of the water. In any case, however, the flow of water and oil should be so adjusted as to avoid chilling the oil and retarding its circulation.

From the foregoing it is evident that as the size of transformers increases the tendency is to provide means of increasing the rate of flow of the cooling oil. If we assume this rate equivalent to one, in the self-cooled type, it will be between two and three times this in the ordinary water-cooled design. With the forced-oil type of transformer, the rate of circulation by artificial means will be increased from three to four times that of the self-cooled type.

Perhaps few persons realize the actual rate at which oil circulates in the various types of transformers; the rate of flow is usually thought to be extremely sluggish. It might be of interest, therefore, to cite a concrete example. Take, for instance, the 7500-kw. transformers recently installed. In these transformers the oil circulates at the rate of 100 gal. per min. while the calculated rate of flow through the various coils and core channels is something like 30 ft. per minute. Based on these figures, which were obtained from actual measurements, together with results obtained from water-cooled transformers designed for a similar temperature-rise, the rate of oil-flow is probably not far from 50 gal. per min. for a 7500-kw. unit, while the oil must pass through the various ducts at the rate of 15 ft. per min. Even the natural circulation, then, due to the difference in temperature alone, is not so slow as is sometimes imagined.

We have now gone over the various means employed for extracting heat from the interior of coils and cores of different types of transformers. We have seen the effect of increasing the oil circulation and of resorting to various methods of water cooling. What the next step will be is hard to foretell. Among other means, however, refrigeration has been suggested and as this presents several advantages over the methods already in use, it may perhaps be considered for certain special designs which will present themselves in the future.

Experience with oil-filled leads. We have now heard something of the development of transformers of large capacity. Not only has the demand for apparatus of large size steadily increased but with it the demand for increased voltage. A few years ago the demand was for apparatus of not over 10,000 or 12,000 volts; to-day the demand is for nearly ten times these pressures. The new conditions have made it necessary to design and build for operating voltages of 100,000 or more, and in some instances for test values of more than 300,000 volts.

While the design of transformers, the internal parts of which would meet these requirements, was difficult enough the problem of bringing out the high-tension leads was one which required perhaps fully as much consideration. It has been customary with apparatus of moderate voltage to rely on leads insulated with wrappings of tape, with the additional protection afforded by porcelain bushings. For still higher voltages, greater insulation was obtained by putting on more tape and resorting to larger porcelain parts. And to prevent surface leakage from the end of the terminals to the case, the lead was either made very long or provided with a number of circular barriers or discs. It became extremely difficult and expensive, however, to use this design for apparatus of 70,000 or 80,000 volts, which required test values of double this amount, but as oil had proved itself an excellent insulating medium for internal construction, the idea occurred to utilize it for external parts as well. The problem was then to provide a suitable structure for holding the oil.

The first oil-filled lead put into service was made up of a series of resin-filled circular wooden sections mounted one on top of the next with pressboard collars between. In later patterns, moulded compound was substituted for the wood, and the oil space inside was broken up into several sections by pressboard tubes extending the entire length of the lead. Openings at top and bottom of these tubes allowed for ready filling with oil and for circulation.

With this design the distance from the end terminal to the body of the lead next to the case is usually about 50 per cent greater than the natural voltage jumping-distance for which the lead is designed, while the length of the creepage path is made about three times this amount by the presence of the pressboard discs. What the final limit of this type of lead will be, is not yet known; it has already been used successfully on commercial apparatus requiring tests of somewhat more than 300,000 volts. Investigations are being made, the results of which it is believed will enable us to reach voltages much greater than 300,000.

One of the desirable features of this type is the ability to distribute the electrostatic strain. This feature perhaps as much as anything else, has rendered this type particularly useful, as any lead which allows concentrated strain at one point is always in danger of ultimately breaking down. Moreover, the oil in the various internal tubes is free to circulate, and thus prevent local heating. Not only has the lead been used to good advantage in high-voltage power transformers, but also in the construction of certain types of series transformers where the problem of bringing out the high-tension leads required careful consideration. Before taking up this phase of the subject, however, it will be well to consider the development of the series transformer up to the point where the oil-filled lead became a necessary adjunct.

Development of the series transformer. Considered historically, the series transformer was first used in connection with a street lighting system. Here its use was a failure, and for 15 or 20 years it played little or no part in electrical work. Then as the demand grew for a device which would give comparatively small current values directly proportional to the larger currents flowing in a line, this transformer again came into commercial use in connection with measuring instruments.

At this time it was in no way considered as a protective device, and although it gave a ratio accuracy which was compatible with the accuracy of the measuring instruments of the period, no attention was paid to refinements of ratio-transformation and phase-displacement. As its use became more general, and the accuracy of the instruments improved, the demand for a more accurate device increased. And with the introduction of higher voltages better insulation was required, insulation that would protect not only the instruments but also the operator.

At that time it was considered essential in order to keep the magnetizing current within reasonable limits compared with the accuracy of transformation, to use a magnetic circuit without joints. This naturally resulted in the adoption of a core built up of sheet-iron rings. The primary and secondary windings were then placed on this core, it being necessary to wind them entirely by hand, the conductors threading through the central opening. The secondary or instrument winding was usually placed next to the core. Then came the insulation put on in the form of tape, and finally the primary winding. This process was somewhat expensive, to be sure, but for small sizes and comparatively low voltages it gave satisfactory results. It is still used successfully where tests as high as 20,000 or 25,000 volts are required.

For voltages higher than this the insulation became a serious problem. The number of tapings had to be increased, which meant time and expense, and even after they were once in place it was difficult to take care of the heat from the windings, unless this had been rendered very low by the use of conductors of large cross-section. To overcome the necessity of using an extensive number of tapings, a new type was developed in which the low-voltage secondary was wound on the core as above, while the insulating medium consisted of telescoping tubes held apart by suitable spacing strips. Part of these were slipped through the inside of the ring and part over the outside, which arrangement provided ample insulation for a direct break between the primary and secondary near the central part of winding. In order to obtain sufficient creeping surfaces between the primary and secondary, where the former passed over the latter, it was necessary to extend the tubes to a considerable distance on either side of the core, to fill in the space with discs of porous material, and then give the whole device a vacuum compound treatment. This treatment served not only to make the transformer moisture-proof but also added greatly to the insulating value of the leakage surface between coils. The result was a transformer which satisfactorily withstood a considerably higher test-voltage and gave good results, although the transformer was somewhat bulky and expensive.

Previously to about three years ago it was considered sufficient to insulate the series transformer with the same margin of safety as that allowed in potential transformers; that is, double the line voltage. Owing to several reasons, however, it was deemed advisable to require an insulation-test of three times that of the operating circuit. In the first place, the secondary of a series transformer is usually grounded; being the first apparatus in the path of a lightning discharge, it often receives the entire blow and acts in the capacity of a lightning-arrester. Moreover, it furnishes current not only to the measuring instruments but also for the various limiting and protecting devices. It is, therefore, often the keynote, so to speak, of the whole switchboard equipment. The fact, too, that the safety of the attendants depends on the insulation of this piece of apparatus makes the triple-voltage ruling doubly important. It meant, however, the addition to the standard line, of a transformer for 15,000-volt circuits which would withstand an insulation test of 50,000 volts. One was naturally developed along the lines previously described. Though the resulting transformer that met all requirements successfully, it was of rather large dimensions, expensive to construct, and required, due to the method of insulation, a rather long time to manufacture. Consequently, time and thought were put into the development of a new type that would lend itself more readily to high voltages and at the same time would be less expensive, and would require less time to make.

It is evident that the methods used for the insulation of a transformer built on a core without magnetic joints were the only ones that appeared at all practicable. In consequence, in considering the development of a new type, it became necessary to investigate the use of a core having one or more joints, it having been previously thought that those of the jointless type were cheaper to build. Contrary to belief, however, it was found that a design could be developed by using a core having joints which not only would be cheaper but at the same time more accurate than those previously constructed.

When these points were proved, it was natural to utilize the U-shaped punchings which had been so long in successful use in the construction of the core-type transformer. This, then, resulted in the adoption of form-wound coils, the secondary and primary being wound separately and receiving enough varnish tapings to stand the required test-voltage. The coils were then assembled on one leg of the core, with the secondary next to the iron and the primary slipped over it, the core being suitably clamped to the frame which furnished support for the secondary terminals and feet for the mounting of the device as a whole. The resulting transformer had many advantages over the older type, but still left things to be desired, the most prominent of which was shortening of the time required to produce it.

About this time there were great strides in the use of moulded insulation, and the idea occurred to utilize such material in connection with high-voltage series transformers by moulding it completely round the primary coils. This was accomplished only after many trials; for it should be remembered that not only must the compound be a good insulator electrically but also a good heat conductor; it must be mechanically strong, and designed to withstand repeated expansion and contraction; and it must be capable of being formed round the coil at not too high a temperature, otherwise the cotton covering of the conductor would be ruined. In addition to these requirements, the preparation must not soften at operating temperatures, and must not be too expensive. In spite of these numerous conditions, a compound meeting them all was developed.

During the first attempts to use this compound, the enclosing casing was moulded in halves, these being placed round the coil and sealed together. During test, however, weakness developed at the joints, and this form was abandoned. The arrangement finally adopted, the one now successfully used, consists of a complete compound ring the sides of which are open at the top. The primary coil is placed in this ring and the open sides are folded over and forced together under a pressure in excess of two tons per square inch, at a temperature of about 200° cent. The result is a coil with suitable leading-out terminals enclosed in an insulating casing without a single joint or seam. It readily withstands a test of 50,000 volts. In fact it will not break down at much less than 80,000 volts. This, then, results in a series transformer that is absolutely safe for operation on 15,000-volt circuits, is neat in appearance, is less expensive to build, and can be made in a much shorter time.

In passing, it is interesting to compare the length of time consumed in insulating coils with tape, using the original method, with that required to produce a coil insulated as just described. The first method necessitates the use of many layers of tape, each having a number of varnish treatments, and the total time required for insulating is more than 20 days. The new method requires 30 min.

Up to this point we have considered the use of dry types only, requiring tests as high as 50,000 volts. On general principles, however, it would be preferable to resort to oil much below this point. But this has not been considered advisable, owing to the strong preference to avoid its use in switchboard construction.

Oil is used, however, for all transformers requiring a pressure test of more than 50,000 volts. The arrangement of coils and core in this type of transformer is somewhat similar to that previously described for the lower voltage dry transformer using ring-punchings. The usual practice is to wind the secondary directly on the core and to provide a number of tabular barriers, nested one within the other with oil spaces between for insulation, the primary being threaded through as already mentioned. This construction, combined with the oil-filled lead previously described, has been used successfully for apparatus requiring tests as high as 300,000 volts,

Recent designs of lightning transformers. Turning now from some of the larger types of apparatus used more particularly in transmission and central station work to some of the smaller transforming devices. It may be of interest to refer briefly, first, to lighting transformers. A great deal of attention has been given to this type in the way of reducing losses, improving the operation, and lowering the cost without affecting durability and safety.

Considering one particular size, the 5-kw. size for example, it was usual 10 years ago to find the core-losses approximating 90 watts or more. Improvements in material and design brought this core-loss down to 80 watts, and still later to 70 watts when silicon-iron was introduced. Then an entirely new form was designed and the core-losses were again reduced 10 per cent or 12 per cent, bringing them to slightly more than 60 watts. During the last year still another improvement has been made in transformer iron; by taking advantage of this improvement and again modifying the design, the core-loss on the 5-kw. size was reduced to 45 watts. Thus, in 10 years' time, by steady improvement in design and by using the best material, the core-loss has been reduced to half its original amount. During the same time the quality of the apparatus has steadily improved and the cost of manufacture has been lessened.

There are several features of interest in the latest design of a certain kind of transformer which it might be well to mention. Perhaps the most noticeable is the symmetrical arrangement of coils and core, and the ingenious interlocking of the latter in the central leg. These features together with a correct proportioning of parts, has resulted in a relatively short mean-length of iron and copper circuits; this is but another way of saying that the transformer contains a minimum amount of material for given losses.

Another important feature of this design, but one not so evident at first sight, is the restricted area in the central core. This brings about two results: first, the shortening of the mean length of turn in the copper circuits; secondly, an increase in flux-density in the central leg of the magnetic circuit. Such an increase in density results, to be sure, in higher losses in this part of the core, but they occur in only a comparatively small part and are more than offset by low losses in the four external magnetic circuits, where the area of cross-section can be made large without in any way interfering with the space occupied by the winding.

Tungsten-lamp compensator. In the first part of the paper mention was made of some of the larger sizes of transformers. We will refer now to one of the smallest types manufactured, that known as the tungsten-lamp compensator. This device was developed to accommodate low-voltage tungsten lamps to standard circuits, usually reducing the latter voltage in the ratio of about 4 to 1. It is so arranged that it can be inserted in an ordinary lamp socket. It is of interest not only because of its small dimensions but also on account of its somewhat unusual efficiency characteristics.

Fortunately, in the device we are considering, not only is the capacity small, 25 watts, but the voltage requirements are low, and it has therefore been possible by careful design and correct proportioning of material to obtain an efficiency of over 85 per cent. What is of equal interest perhaps is that this efficiency is maintained for voltages ranging from 110 to 130 and for loads ranging from full to less than half.

Where we have the ordinary line pressure of 2200 or 2300 volts to contend with, the amount of active material, made necessary by the space required for insulation, is comparatively large. This has led to the impression that small transformers must necessarily have low efficiencies, so that in the case of one of 25 watts' capacity, for example, 60 per cent or 70 per cent at full load would not be thought unreasonable, this falling to perhaps 40 per cent or 50 per cent at half load.

By comparing these values with those mentioned a moment ago, it will then be seen that if the conditions are favorable the efficiency of even small transformers can be made comparatively high.

Hardening and annealing furnace. An outline of recent developments in transforming devices would hardly be complete without mention of the electric furnace. This is too broad a subject to consider here, so only one type will be touched upon and this very briefly—the electric annealing and tempering furnace.

For many years, as we all know, it has been customary in the process of annealing and tempering to resort to coal- or gas-heated furnaces, the metal to be treated being exposed either directly to the flame or packed in some heat-conducting material. These methods all have their disadvantages, however, one of the most serious being the difficulty experienced in raising the temperature uniformly to the desired value, and then maintaining it for the required length of time.

The lead bath and the cyanide process, too, both have their limitations and disadvantages.

The electric annealing and hardening furnace, which has been developed during the past few months, has, on the other hand, many valuable features which are not present in the devices just mentioned. Its bath is composed either of pure barium chloride, of a mixture of the chlorides of barium and potassium, or, in some cases, of a mixture of potassium chloride and sodium nitrate, depending on the temperature at which it is desired to operate. By selecting the proper mixture then and adjusting the current which flows directly through the bath, any temperature from 200° cent. to more than 1300° cent. can be obtained and held at a perfectly uniform value. These features, together with the fact that the bath used does not in any way affect the composition of material which is to be treated, makes the device exceedingly useful and valuable.

The electrical part of the equipment consists of a transformer and regulator connected to a suitable dial switch. By means of this arrangement, the voltage may be varied by small amounts over a wide range, thus making it possible to obtain any current desired.

Having thus heard something of the development of various lines of apparatus, from a transformer having a capacity of a number of thousands of kilowatts, and required to withstand an insulation test of several hundred thousand volts, down to one designed for a lighting circuit and weighing but a few ounces, it may be of interest to consider briefly the very complete equipment provided for testing the finished product.

Transformer Testing equipment. The questions of testing and testing-equipment became extremely important with the centralization of practically all of the transformer manufacture, and therefore, in the particular installation that I have in mind, it was only after a great deal of thought and study that the present layout was decided upon. This study included a review of the apparatus tested in the past and that likely to be tested in the future, together with an examination of the equipments in existence in the various testing departments.

The first requisite laid down was absolute safety to life; the second, safety to property. The third and fourth were accuracy and the providing of an equipment which would enable the maximum amount of work to be turned out with minimum time and labor.

The equipment as now installed is entirely non-combustible—the floors are of concrete, the framework of piping and angle iron, and the switchboard of slate and marble.

All voltages above 500 are considered dangerous and are treated accordingly, by protecting them and keeping them out of reach. In general, the wiring is either on the back of the switchboard and entirely protected by screens or is in conduits underneath the floor. Machine frames, transformer cases, switch boxes, etc., together with the secondaries of the current and potential transformers are grounded, and by means of metal strips running along the floor the tanks or cases of all apparatus which is under test should likewise be connected to earth. Practically all switches except those for low-voltage circuits are of the oil type and placed back of the board so as still further to reduce the danger.

The individual testing boards and tables are arranged as closely as possible to the work in hand, so as to make possible the use of short cables leading up from the transformers to the proper line terminals, and thus reduce the temporary connections to a minimum. This simplification and reduction of temporary wiring, perhaps as much as any other feature, serves to lessen danger to life and to facilitate the testing.

To reduce the fire-risk and at the same time to facilitate the making of connections, etc., a pit 7 ft. deep, from 14 to 20 ft. wide, and over 130 ft. long has been installed in which are placed all oil-filled transformers while in test. This pit is provided at one end with a 30-in. drain-pipe leading to the river so that in case of fire the oil can be readily removed. As a still further safeguard, a 2-in. pipe connected with the live-steam supply has been arranged for. This will make it possible to smother a fire by steam should oil at the bottom of the pit become ignited. All oil for testing is stored under ground and entirely away from the main building. When it is considered that the testing equipment is located in the midst of a floor area of more than 9 acres, 60 per cent of which is covered by one roof, the importance of these precautions cannot be overestimated.

Every switchboard and every generator is provided with a pilot lamp so that the operator can see their condition at a glance.

The majority of the generators and the testing transformers have their windings arranged in eight sections so that they may be grouped all in series, all in parallel, or in series-parallel. This construction, together with the regulating winding and field control, makes it possible to obtain any desired voltage at a moment's notice. The eight-section arrangement is carried out also in the three-phase apparatus as well as in the single phase; that is, each phase is divided into eight equal parts so that star, delta, or independent phase connections can be made over a very wide range of voltage. The ammeters for these machines instead of being inserted in the outside circuit, as is customary, are connected into one winding only, so that regardless of the arrangement of connections, the instrument indicates at all times the proportionate load being carried. This largely eliminates danger of overloading due to the numerous forms of connections which are possible.

The fields of all generators and motors in the test, both alternating current and direct current, are designed for excitation at 125 volts and have a resistance such that the controlling rheostats may be entirely cut out and machines operated in this condition continuously without overheating.

Each direct-current generator is provided not only with an ordinary circuit-breaker and no-voltage release, but also with a speed-limiting device which automatically cuts the machine out if the speed exceeds a certain predetermined value.

The ratio-transformers are all made for 25 cycles and cannot be burned out at low frequencies, an accident which has occurred more than once when those of 60-cycle design were available.

In addition to the precautionary measures mentioned, many of the switches connecting transformers, etc., are provided with interlocking devices, making it virtually impossible to obtain connections which would result in danger either to the operator or to the apparatus.

One operation during the testing of transformers, particularly when they are of large size, and one which has always required a large amount of time and expense, is the heat run. Even when this is hastened by an overload, as has usually been customary, a number of hours elapses before the cold oil is brought up even to normal operating temperature, and moreover all heat must be supplied electrically. These two drawbacks have been overcome in the new equipment, by heating the oil by steam before it is forced into the transformers. The oil as it comes from the heater is stored in a large tank where it can be drawn off as required, and on the completion of the heat-run the oil from the various pieces of apparatus is again pumped back into this tank so that its temperature can be maintained at a comparatively small cost.

Another saving has been introduced in connection with the use of water for cooling water-cooled transformers. One of the conditions of test is that this incoming water shall be maintained at a uniform temperature of 15° cent., which means that during winter weather every gallon used must be raised at least 10 degrees. This has ordinarily been accomplished by passing it through some type of heater, allowing it to escape into a drain after accomplishing its purpose. In the new equipment, the water discharged from each transformer is led back to the receiving tank and mixed with the cold incoming water in such proportions as to maintain a temperature of 15 degrees, thus saving the expense just mentioned. Thermostats and controlling devices automatically maintain this uniform temperature.

To eliminate the effect of low power-factors on the main generating plant, and to add to the flexibility of the testing equipment, the two-phase, 60-cycle power, as originally generated, is not taken from the incoming lines until it has passed through motor-generator sets, these sets being installed on the floor of the testing room. By suitable excitation, then, the power-factor of the generating station is maintained at a remarkably high value, usually about 97 per cent, while the power-factor of the testing load varies between 10 to 40 per cent, averaging not over 25 per cent.

The various individual testing boards are provided with similar sets of current and potential transformers, voltmeters, ammeters, and wattmeters —all of which are connected to special switches by permanent wiring. These arrangements are so complete that the man in charge of a test, by merely throwing certain switches, can measure any loss or load from 37 volts to 15,000 and from 0.5 to 500 amperes at power-factors ranging from 10 to 100 per cent, while frequencies of 25-30-40-50-60, or 80 can be obtained at a moment's notice.

All things considered, the equipment in point of safety to life, efficiency of operation, and general arrangement, is, so far as I know, the most complete of its kind.

Sections and Branches

ARMOUR INSTITUTE OF TECHNOLOGY BRANCH

Sixty members and guests of the Armour Institute of Technology Branch attended the meeting held in Chapin Hall on February 11, 1909, to hear a paper by Mr. R. H. Rice, of the Board of Supervising Engineers, Chicago Traction, on " Some Problems Connected With the Building of a Large Street Railway System." After outlining the development of the supervising board, Mr. Rice dealt with each department of the railway system in a general manner. Illustrations were used to show the general methods of procedure of each division, and he then took up in detail the work of the division of power distribution with which he is directly connected. He gave much interesting and valuable information on the underground, overhead, track and conduit construction, together with feeder layouts and special problems connected with them. He also illustrated the use of curves and tables of constants by which the work of the supervising board is greatly facilitated. The paper, considered by those present a most excellent one, was followed by a general discussion.

ATLANTA SECTION

The Atlanta Section, which has resumed activity, held a meeting on February 2, 1909, at the Heptagon Club. In the absence of Chairman Collier, Mr. A. M. Schoen presided. There were informal discussions on the subjects of circuit-breakers, and the power-factor of arc-lamp circuits.

The March meeting, held in the Grand Building on March 2, 1909, was devoted to a discussion on Dr. C. P. Steinmetz' Institute paper on "Prime Movers." Mr. G. J. Yundt agreed to give a paper on "Wireless Telephones." Mr. Bonyun and Mr. Wynn both promised papers for future meetings. There was a total attendance of 15. Mr. M. E. Bonyun presided in the absence of Chairman Collier.

BALTIMORE SECTION

The Baltimore Section held its regular meeting at Johns Hopkins University on February 16, 1909. Dr. J. B. Whitehead was the presiding officer, and the total attendance numbered 52. The paper of the evening, "Modern Storage-Battery Practice", was read by Mr. R. C. Hull, district engineer of the Electric Storage Battery Company, and was illustrated by lantern-slides.

BOSTON SECTION

The regular monthly meeting of the Boston Section was held at the Edison Building, Boston, on February 17. Professor Elihu Thomson reviewed his recent paper read before the Institute on "Conditions Affecting Stability in Electric Lighting Circuits." An extended discussion on arc light dynamos was held at the conclusion of the paper.

UNIVERSITY OF CINCINNATI BRANCH

At the meeting of this Branch held February 23, 1909, Dr. Taylor read a paper on the "Mercury Arc Rectifier", which led to considerable discussion by Messrs. Biédinger, Ackerson, and Winder.

CLEVELAND SECTION

At the meeting of the Cleveland Section held on February 22, 1909, Mr. Roberts offered the following resolution: "That this Section communicate with the other Sections and with the New York office in an effort to stir up sentiment in favor of changing the present custom of nomination of officers of the Institute." This resolution was discussed at length by several of the members, and an amendment carried that a copy of the resolution, when revised, be sent to the secretary of each Section and to the New York office.

The subject of the evening was then introduced; "The Purchase of Fuel on a Calorific Value Basis", by Mr. L. P. Crecelius, of the Municipal Traction Company. The paper covered the purchase of fuel for a large power plant. Some interesting discussion on the subject was contributed by Dr. Smith. Professor Fernald followed with an illustrated talk on the utilization of low-grade fuel by means of gas producers, and gave an encouraging report of what was being accomplished in the government testing laboratories, in which he is a mechanical engineer. Mr. Woodward, of the city water-works department, also gave some interesting information on specifications for fuel furnished to the department. The attendance at the meeting was about 75.

UNIVERSITY OF COLORADO BRANCH

December 17, 1908. A meeting of the Branch was held on this date in the engineering building. Mr. R. E. Robertson read a paper on "The Wiring of Sky Scrapers," describing the general wiring of the buildings. He gave also some attention to the location of the power plants. Mr. Walroth read a paper on "Arc Lamps." He described the various types, including the magnetite and flaming arc.

At the meeting on January 7, 1909, Mr. H. H. Watters read a paper on "Insulation." His talk was illustrated, and he dealt with practical insulation for high-tension service. This meeting was well attended, there being 40 present.

At the meeting on January 21, 1909, a paper was read by Mr. V. E. Metcalf on "Materials for Overhead Electrical Construction." Mr. Metcalf gave details for building steel towers, and told of the use of aluminum cables. Mr. Wheeler took up the subject of the "Synscroscope," describing the Lincoln and induction types.

February 18, 1909. The program for this meeting consisted of a practical talk on meters, by Mr. E. L. Siekman, of the Northern Colorado Power Company.

FORT WAYNE SECTION

The regular meeting of the Fort Wayne Section was held in the rooms of the Fort Wayne Engineering & Manufacturing Company on Thursday evening, February 11, 1909, at which there was a good attendance including a number of visitors. The Section considered a change in the place of holding meetings in order to obtain rooms better suited for its purpose. Owing to the absence from the city of Mr. M. J. Kehoe, it was decided to postpone the consideration of his paper until the following meeting when he could be present. Instead, the program consisted of a discussion on "Electrical Heating", by Mr. J. J. A. Snook. Considerable discussion followed, several of the railroad engineers present taking up the subject of electric heating of cars, and others giving their attention to electric welding.

The March meeting was held on the evening of Thursday, March 11. Many of those present were visitors from the railroad engineering profession, attracted by the subject for the evening. After transacting the unfinished business, the chairman introduced Mr. T. R. Cook, who presented a paper on "Electric Car Lighting." Mr. Cook took up the subject in the sequence of the four principal methods which up to this time have been used for the purpose of car lighting, as follows: first, the straight storage-battery system, using from 30 to 60 volts pressure, this system consisting of individual storage-batteries for each car. Secondly, the axle-generator system, in which the machines driven from the car axle are augmented by the storage-battery system. Thirdly, the head-end system in which the prime mover is installed in the baggage car. Fourthly, the head-end system with the prime mover consisting of a steam-driven generator mounted on the locomotive. Mr. Cook expressed it as his opinion that the axle-generator system is by far the most preferable, owing to the fact that in this system each car is individually equipped and could take care of its own needs, whereas in the storage-battery system it required terminal facilities to charge the storage batteries in each car at each end of the run. He stated that he considered the axle-generator system superior to the head-end system, owing to the inefficiency of the prime mover installation in the latter and the trouble occasioned in effecting an efficient transmission throughout the train. He also stated a number of other reasons that made the head-end system undesirable. A discussion by a number of the members present in regard to other lighting systems concluded the program for the evening.

IOWA STATE COLLEGE BRANCH

The last meeting of the Branch for the year 1908 was held on December 2, and was devoted to the election of officers for the spring semester. Mr. Frank K. Shuff was chosen chairman, and Mr. M. W. Pullen secretary. Messrs. Zornig, Warsaw, and Fish were elected members of the executive committee. Messrs. Kirkpatrick, Mills, and Paine were appointed a social committee. A vote of thanks was tendered to Professor F. A. Fish, the retiring chairman, and to Professor Adolph Shane, the retiring secretary.

The first meeting of the new year was held on February 3, 1909. The evening was spent in discussing the vacation experiences of the various members. The inspection trip to Chicago and Milwaukee seemed to be the favorite topic, with thesis work a close second. Professor Meeker gave a short talk on " Conservation of our Natural Resources."

The second regular meeting of the month was held on February 17, in engineering hall, and was well attended, 60 being present; 39 members of the Branch, and 21 visitors. Mr. H. B. McElyea gave a paper on " The Equipment of the New York, New Haven & Hartford Electric Railroad." The paper was discussed by Messrs. Shuff, Shane and Fish. Mr. Joe King reviewed Mr. W. S. Murray's Institute paper " The Log of the New Haven Electrification." This was discussed by Messrs. Shuff, Fish, Shane, King, Pullen, Stanton, Kirkpatrick, McElyea, and Meeker.

The next regular meeting was held on March 3, 1909, with a total attendance of 42. Mr. R. C. Crouse reviewed the Institute paper on " Electric Heating. Mr. H. N. Kalb reviewed the Institute papers on " The Grounded Neutral ", published in the September 1907 PROCEEDINGS.

ITHACA SECTION

The meeting held February 19, 1909 was devoted to a discussion of Mr. W. S. Murray's Institute paper on " The Log of the New Haven Electrification." A digest of this paper was delivered by Mr. P. A. Bancel, and illustrated by specially prepared lantern-slides.

The Section had its annual dinner on Friday, March 5, 1909, in the Sibley College club rooms. Seventy-five members of the Section were present. Mr. D. B. Rushmore, of Schenectady, was the guest of honor, and Professor E. L. Nichols officiated as toastmaster. After an enjoyable menu a number of toasts were given. by the deans of the different colleges and the heads of various departments. In responding to the toast on " Speed Graphs, or Acceleration on the Motor Curve ", Professor Norris gave an interesting analogy between the speed control of the railway motor and the influence of the professor upon the working rate of the student. The annual dinner has become an established feature, and adds materially to the enthusiasm of the members.

Following the dinner Mr. Rushmore addressed 125 members of the Section on the subject of " The Application of Electricity to Steel Mills." The address was illustrated by lantern-slides showing the various processes in the making of steel, including the mining of the ore, its transportation and unloading, conveyance to the blast furnaces, rolling, sawing, and drilling of the steel product. Especial attention was directed to the use of the electric motor in these processes, and an excellent idea was given of the hard service and rugged nature of these powerful motors.

The executive business consisted of the acceptance of the resignation of Professor H. H. Norris as secretary of the Section, which office was filled by the election of Mr. B. C. Dennison. Professor Norris will continue, however, to maintain active interest in the work of the Section.

KANSAS STATE AGRICULTURAL COLLEGE BRANCH

A meeting was held on November 10, 1908, in the chemistry lecture room of the college, at which Mr. C. C. Howenstine gave a talk on " The Electric Locomotive ", using as a basis for his remarks an article appearing in the Electrical Review October 17, 1908.

No meetings were held in December or January.

On February 2, 1909, a meeting was held in the electrical engineering laboratory. Twenty-three members and guests were present. Mr. Roy Wilkins opened a discussion on " Voltage Regulators ", Messrs. L. L. King, E. W. Jones, and C. C. Bonebrake taking part. The Institute paper on " Electric

Heating" was reviewed by Mr. A. S. Salkeld. A demonstration and discussion of "Ground Detectors", given by Chairman W. L. Enfield, concluded the program.

On March 2, 1909, there was an attendance of 44 persons. At a former meeting it had been decided to give a practical demonstration of some electrical phenomenon at each meeting, with a view to increasing the interest of underclass men. For this reason the March meeting was held in the electrical engineering laboratory. Professor Elihu Thomson's Institute paper, "Conditions Affecting Stability in Electric Lighting Circuits", was discussed by Mr. F. H. Mayer, who was assisted by Mr. C. L. Kipp and Mr. Hugo Schild. A demonstration with alternating currents, including a pressure of 60,000 volts, was given by Professor B. F. Eyer. In conclusion Mr. W. C. Lane, secretary of the Branch, gave a brief review of Dr. C. P. Steinmetz' Institute paper on "Prime Movers."

UNIVERSITY OF KANSAS BRANCH

At the meeting of this Branch held on February 23, 1909, it was voted to change the meeting night from alternate Thursdays to alternate Wednesdays. Professor M. E. Rice addressed the meeting, his subject being "Problems Confronting Engineers of To-day." He was followed by Mr. Leonard Pulliam, who reviewed the Institute paper on "Electric Heating." Both papers were discussed. There was a total attendance of 16.

The next meeting was held on March 4, 1909, at which the total attendance was 20. No business was transacted. Mr. W. F. Thiele and Mr. George Ahlborn led a discussion on "The Conversion of Alternating Currents to Direct Currents." Mr. Thiele spoke of converters in general, while Mr. Ahlborn dealt more especially with the split-pole converter.

LEHIGH UNIVERSITY BRANCH

A number of papers were presented at the January meeting of this Branch, held on January 12, 1909, and there was a good attendance. The program was as follows: "Interior Wiring"; a talk from an extended practical experience by Mr. O. P. Serfass. Prices and problems ordinarily met with were given. The second talk was by Mr. Bason. This was a description of a trip recently made by the senior electricals to New York power plants and to the General Electric Company. Mr. Brumbaugh concluded the program with a talk on "Shop Practice", dealing with repair and trouble work in a railway motor repair shop.

The February meeting of the Branch was held on Tuesday evening, February 16. The program consisted of two papers. The first was by Mr. C. E. Clewell, on "Train Resistance." Mr. Clewell gave and explained two formulas for determining such resistance, one due to Davis, and the other used by the Baldwin Locomotive Company. The second paper was by Mr. Lamar Lyndon, on "Construction of High-Tension Transmission Lines." Mr. Lyndon gave the three prime conditions to be met in such lines: first, the amount of energy to be supplied at the other end of the line; secondly, distance from source to point of distribution; and, thirdly, character of load. He worked out many problems to show the best working conditions for a line to be operated under given specifications. The subject aroused much interest. At the conclusion of Mr. Lyndon's remarks the meeting was adjourned for the usual refreshments.

LEWIS INSTITUTE BRANCH

The February meeting of this Branch was held in the auditorium of the Lewis Institute on the evening of February 17, 1909. Professor Woodworth gave a talk on the subject of "Electrolysis of Copper Sulphate." The various theories extant regarding electrolytic dissociation were presented and compared. The lecture was supplemented with numerous experiments designed to show some of the phenomena associated with electrolysis. The phenomenon of increased conductivity with extreme dilution of the electrolyte was also discussed, and tables giving the conductivity of electrolytes of various degrees of dilution were shown. At this point, an X-ray tube was operated and some of the phenomena associated with its operation were brought out. A comparison was then drawn between the physiological effects produced by the X-ray and that of the extremely dilute solutions of copper sulphate, and it was shown that in both cases the peculiar effects were probably due to ions moving at very high velocities. The efficiency of copper sulphate in very dilute solutions as a germicide were also discussed, and some of its applications were given.

Los Angeles Section

This Section held its regular meeting on February 16, 1909, at the University of Southern California, with 32 Institute members and 28 visitors in attendance. The business consisted of the election of local members. At the conclusion of the business, Mr. R. J. C. Wood presented a paper on "Limitations in Hydroelectric Transmissions." Mr. C. W. Koiner presided at the meeting.

Madison Section

A joint meeting of the Madison Section with one of the sessions of the Engineering Society of Wisconsin, a new organization, was held in the auditorium of the engineering building of the University of Wisconsin on February 24, 1909. The total attendance was 150. The meeting was presided over by Dean F. E. Furneaure, of the College of Engineering. The program consisted of a paper on "Forest Conservation in Wisconsin", and was presented by Mr. E. M. Griffith. It led to an extended discussion regarding the effects of forests on water powers. Several members of the state legislature were present and participated in the discussion.

Minnesota Section

At the meeting of the Minnesota Section held February 15, 1909, the following named officers were elected to serve to August 1, 1910: chairman, Mr. Barry Dibble, St. Paul, Minn; secretary, Mr. J. C. Vincent, Minneapolis, Minn.; executive committee, E. P. Burch, Arthur L. Abbott. By-laws were adopted as follows:

BY-LAWS OF THE MINNESOTA SECTION OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Sec. 1. *Scope.* These by-laws are intended to supplement the Constitution and By-laws of the American Institute of Electrical Engineers, and in case of any conflict between them, the Constitution and By-laws of the Institute shall govern.

Sec. 2. *Name.* This organization shall be known as the Minnesota Section of the American Institute of Electrical Engineers, as authorized by the Board of Directors of the A. I. E. E. assembled in New York, April 7, 1902.

Sec. 3. *Membership.* All Members and Associates of the American Institute of Electrical Engineers resident in the State of Minnesota shall be regarded as members of the Minnesota Section. Other persons having the qualification for Associates of the American Institute of Electrical Engineers may become "Local Members" of the Section upon election by the Executive Committee and payment in advance of dues of two ($2.00) dollars per annum. Local members shall be entitled to advance copies of Institute papers (but not to the PROCEEDINGS or TRANSACTIONS) and to vote for officers of the Section and to all other privileges of membership except as hereinafter provided. Enrolled Students of the Institute may be regarded as local members but shall be exempt from the annual dues.

Sec. 4. *Meetings.* Regular meetings shall be held monthly from October to

June inclusive on the second Monday after the New York meeting unless otherwise directed by the Executive Committee. Special meetings may be held as desirable.

Sec. 5. *Officers.* The officers of the Section shall be a chairman, a secretary and an executive committee, all of whom shall be Members or Associates of the Institute. The chairman shall perform the duties usual to the office, and other duties as provided by the Constitution of the Institute. He shall ex officio be chairman of the Executive Committee. The secretary shall perform the duties usual to the office and other duties as provided by the Constitution of the Institute. He shall also perform the duties of treasurer of the Section, and he shall ex officio be secretary of the Executive Committee. The Executive Committee shall consist of five members; viz., the chairman of the Section, the secretary of the Section, the junior past chairman of the Section, and two members elected by the Section, one elected each year for the term of two years. The Executive Committee shall meet monthly from September to June or oftener, as may be necessary. Meetings of the committee may be called by the chairman or by joint notice of two members. A quorum for the transaction of business shall consist of three members. The committee shall pass on all matters affecting the general policy of the Section, shall arrange suitable programs for the meetings of the Section, and shall act as an advisory board for the chairman and secretary of the Section. Each committee of the Section appointed or elected after the adoption of this by-law shall include in its membership at least one member of the Executive Committee. In the absence of the chairman from any meeting the senior member of the Executive Committee present shall be the presiding officer.

Sec. 6. *Election of officers.* The election of officers of the Section shall be held at the regular May meeting. Their term of office shall begin on the first of the following August. All officers shall continue to perform the duties of their respective offices until their successors are elected and duly qualified except that in the case of the death or resignation of an officer the Executive Committee may fill the vacancy for the unexpired term. The form of nomination and election of the officers shall be prescribed by the Executive Committee.

Sec. 7. *Amendments.* These by-laws may be amended by a favorable vote of a majority of the full Executive Committee ratified by a majority of the members of the Section present at a regular meeting.

At the conclusion of the business session Dr. H. T. Eddy, dean of the Graduate School, University of Minnesota, presented a discussion of Dr. C. P. Steinmetz' Institute paper on " Prime Movers."

UNIVERSITY OF MICHIGAN BRANCH

No meeting of this Branch was held in January. On February 17, 1909, a meeting was held in the engineering building, 21 members and 27 visitors being in attendance. Mr. McOmber, an instructor in the engineering department of the university, gave a talk on "Apprentice Courses", laying particular stress upon the Westinghouse course.

The largest meeting of the season was held on March 3, 1909. There was a total attendance of 121 at this meeting. Professor Gardner S. Williams, head of the department of civil engineering in the university, delivered an address on " Hydroelectric Installations." The address dealt with the hydraulic end of the plants. The following points were discussed. 1. Methods of determining the head and flow. 2. Average discharge of the stream from rainfall and drainage, 3. Study of floods, etc., from records. 4. Calculation of power from head and average flow. 5. Units to be installed as depending upon h.p. and 6, 12 or 24-hour rate. 6. Type of wheels.

UNIVERSITY OF MISSOURI BRANCH

The University of Missouri Branch held a meeting on February 19, 1909, Professor A. E. Flowers presiding, with a total attendance of 21. Professor Flowers reviewed the Institute paper "Conditions Affecting Stability in Electric Lighting Circuits," and presented data as to increased luminous efficiency of the alternating-current arc by use of series inductance instead of resistance. Mr. McAdam mentioned additional cases of unstable working of electrical apparatus, and spoke also of the operating characteristics of constant current machines, quoting from a report of the New York meeting. Messrs. Boggess, Schmander, and others took part in the general discussion which followed.

MONTANA AGRICULTURAL COLLEGE BRANCH

The regular monthly meeting of this Branch took place on February 15, 1909, in the electrical lecture room, 18 members and visitors being present. Mr. O. S. Peters reported that the electrical number of the college paper would be its March issue. Mr. Lisle Henderson then gave an abstract of Mr. W. S. Murray's Institute paper, "Log of the New Haven Electrification. The points taken up were principally the faults in the construction and operation of the road. A few of these were, briefly, overheating of generators on overload; breaking down of the insulation, which had to be doubled on the entire line; breaking down of the circuit breakers. Another point mentioned was the wearing of the copper wire by the trolley shoe, a defect overcome by running the trolley on a steel wire suspended from the copper one. A general discussion followed the reading of the paper.

NEW HAMPSHIRE COLLEGE BRANCH

At its meeting held January 8, 1909, the Institute Board of Directors authorized the organization of a Branch at the New Hampshire College, Durham, N. H. The organization was effected on February 25, and by-laws adopted. The following officers were elected: chairman, A. M. Buck; secretary-treasurer, E. R. Fellows; executive committee, A. M. Buck, E. R. Fellows, P. F. Ellsworth. Beginning with Monday, March 1, meetings will be held every other Monday.

The first meeting of the new Branch was held Tuesday night, March 2, 1909, in the physics lecture room of Conant Hall, with a fairly good attendance. After the business meeting two papers were read on the subject of electric heating; one by Mr. O. D. Goodwin, entitled "Domestic Uses of Electricity", and the other by Mr. F. E. McKone, on "Commercial Heating as Applied to Electric Cars." In both of the papers it was shown that steam power could not compete with gas in the production of electricity for heating purposes, on account of the low efficiency and consequent high cost of the production of electrical energy by steam power. In the ensuing discussion a number of interesting points were brought out. Professor Cardullo, in the course of his remarks, spoke of the use of the thermodynamic engine in connection with refrigerating machinery for use in heating. This engine could be operated with a small amount of power between two temperatures, one above and one below atmospheric, and therefore this could be used to heat houses in winter and to cool them in summer, simply by reversing the discharge at the different times. Professor Hewitt discussed the possibility of producing electrical energy cheap enough to compete with gas for heating. This is done where water power is available. Among the places mentioned were Grand Rapids, Mich., and the Ontario Power Company, where a large amount of energy is used for heating purposes both commercially and for domestic use. Professor Buck also contributed to the discussion.

The second meeting was held on March 8, at 3:30 p.m., with an attendance of 62 members and visitors. The speaker for the evening, Mr. Howard L. Coburn, mechanical engineer, of Boston, was introduced by Professor Hewitt, to whom the Branch is indebted for securing Mr. Coburn's presence. In his introductory remarks Professor Hewitt pointed out the great increase in concrete construction in recent years, stating that in 1893 there were about 2,500 barrels of cement used for this work, while in 1903, only 10 years later, there were nearly 25,000,000 barrels used. He then introduced Mr. Coburn, who spoke of the different types of dams built by the company which he represents, and the difficulties one might experience in building dams in different places. The simplest forms of dams are for low heads and earth foundations, those of New England being good representatives of this type, and they are usually built of wood, being logs piled up in an A form upon which planks are placed on the upstream side. Mr. Coburn described five different types of dams built by his company, all of them being hollow on the inside and each adapted for the special place for which they are designed. To show the strength of the structures an illustration was given of a dam in Pittsfield, Mass., which had been built on a foundation of yellow clay, supposed to make a good base, but in this case there was a sudden flood after the water had been very low, and a large amount of clay was washed out from under the dam, leaving it suspended in the air. It was found from measurements taken after this that it had not moved at all, but was as solid as ever. The cause of this clay being washed out was due to the presence of a water-carrying stratum a few feet below the clay, which during the low water period had completely saturated the clay, and when the flood came the clay was too weak to stand the pressure and was washed out. The difference between the reinforced and the solid dam is that the solid one has a flat perpendicular face presented up-stream and the pressure of the water tends to push it down stream, or to overturn it, while the reinforced one is built so that the pressure of the water tends to hold it down, and the greater the amount of water, the greater the pressure; thus there is no chance for the thing to overturn. This is accomplished by making the up-stream side slanting so that the resultant of the weight of the structure and the pressure of the water passes inside the middle third of the base. At the end of the talk a number of slides were shown of installations and different types of water wheels and turbines. It was noticed that in a number of these dams the inside space was utilized for the power plant and also in some cases footpaths and even carriage roads were built through them.

NORFOLK SECTION

The Norfolk Section held its monthly meeting at the Victoria Hotel on January 29, 1909, 12 members and three visitors being present. The date of meetings was changed to the last Thursday in each month. A paper on " Wireless Telegraph " was presented by Mr. C. W. Dean.

The February meeting was held in the rooms of the Board of Trade and Business Men's Association, on February 25, 1909. Fourteen members attended the meeting. The subject was " Tests on the Power Plant of the Haverhill Electric Company ", by Mr. C. S. Dean, U. S. Navy Yard. At the March meeting Mr. D. G. Stanbrough is to give a talk on " Power Plant Design."

OREGON AGRICULTURAL COLLEGE BRANCH

On March 1 the first regular meeting of the month was held in the mechanical hall. Mr. C. Christiansen presented an abstract of Mr. C. P. Steinmetz' paper on " Prime Movers ". In the course of the ensuing discussion several of the members of the engineering faculty pointed out and described some of the good and bad features of the principal classes of prime movers. Mr. W. A. Schoel reviewed Mr. W. S. Hadaway's Institute paper on " Electric Heating."

PENNSYLVANIA STATE COLLEGE BRANCH

This Branch has held regular meetings every Wednesday evening since October 14, 1908, excepting through the holiday season, with an average attendance of 60. The officers for the current year are, chairman, E. A. Wilcox; secretary, H. S. Amer; corresponding secretary, Lee F. Adams. Many of the meetings have been held in conjunction with the mechanical and civil engineering societies of the college. The following papers have been presented: " Electrical Conductivity ", by Dr. J. F. Meyer; " Some Phases of Shop Organization and Management ", by Professor Hugo Diemer; " A Study of Fuel Economy in Electric Power Plants From Recent Tests ", by Mr. A. J. Wood; " Municipal Ownership ", by Professor J. P. Jackson; " The Evolution of Transportation ", by Dr. Edwin E. Sparks, president of the Pennsylvania State College; " The DeLaval Steam Turbine ", by Mr. Harry Hayden; " The Principle of Gas Produces and the Industrial Fields to Which Produce Gas Can Be Applied ", by Mr. Charles Lummis; " Engine Houses and Their Accessories ", by Mr. H. P. Meredith; " The Washington, D. C. Terminal ", by Mr. I. C. Minich; " The Dynamometer Car of the Pennsylvania Railroad ", by Mr. C. E. Barba.

A new form of membership was adopted this year which permits the freshmen and sophomores to become student members of the Branch.

PHILADELPHIA SECTION

The regular February meeting of the Philadelphia Section was held February 9, 1909, with a total attendance of 110, Mr. Paul Spencer presiding. The paper presented at this meeting was entitled " The Mechanical Rectification of 100,000 Volts; Its Application to Roentgen Ray Apparatus," by Mr. H. Clyde Snook. The discussion on the paper was participated in by the following named gentlemen: Messrs. Northrup, Ehret, Temple, Snook, Spencer, Hoadley, Leeds, Dougherty, Stevens, Crampton, and MacLeod.

Eighty members were present at the meeting held Monday, March 8, 1909. A paper was presented by Mr. John Myers, on " Electrical Power From Central Stations," and was illustrated by lantern slides. Article II, Section 2 of the Section by-laws was amended to make the term of office of the chairman to coincide with the term of office of the president of the Institute.

PITTSFIELD SECTION

Mr. E. E. F. Creighton spoke to an audience of about 100 members of the Pittsfield Section in the Wendell Hotel on the evening of March 5, 1909. Mr. Creighton's subject was " Lightning Phenomena " and was illustrated with experimental tests. The experiments demonstrated the nature of different kinds of discharges found in lightning study. Tests that have been used by Mr. Creighton in his research work on lightning-arresters were reproduced. The banking up of potential on the end-turns of transformer coils as a lightning discharge comes into a station were shown. Mr. Creighton gave an account of the present status of protection against lightning.

PITTSBURG SECTION

The regular February meeting of the Pittsburg Section was held at Carnegie Institute on February 9, 1909, Mr. W. Edgar Reed presiding. The usual dinner preceding the meeting was held at the University Club. Mr. L. F. Howard, of the Union Switch & Signal Company, presented an original paper entitled "Railway Signaling", which was illustrated by lantern slides. Invitations to attend the meeting were issued to leading representatives of the railway systems in and about Pittsburg. The subject of application of electric signaling to both steam and electric railway systems was considered, and led to a discussion in which the following men participated: Messrs. T. H. Patenall, A. G. Wilson, I. S. Raymer, H. L. Kirker, A. W. Copley, and William Hoopes. The attendance numbered 125.

PURDUE UNIVERSITY BRANCH

An appreciative audience attended the meeting of the Purdue Branch held on January 26, 1909, in the electrical building of the university. There was a total attendance of 54. Professor H. T. Plumb introduced the speaker, Mr. Thomas Donahue, general manager of the Merchants' Heating and Lighting Plant, Lafayette, Ind., who gave a talk on "Buying and Selling of Electrical machinery."

Mr. Donahue dealt with the subject more particularly from a commercial standpoint and said that a hindrance to the commercial side is that there are too many engineers as traveling salesmen who lose sight of the business proper and deal too much in technicalities. He advised those who wanted to command large salaries to become purchasing agents, a field in which tact and politeness receive the real test. He also gave his idea of the best rate system in power handling—the maximum demand rate—and answered questions by members regarding management and the handling of employes in a central station. To students desirous of obtaining work after graduation he dropped the hint that the first essential is a desire to work.

In connection with the heating department of the Merchants' plant a new device, the "commingler", is being tried out. It is a device for heating water by exhaust steam, and those interested were invited to inspect the apparatus. This heater was originated by Mr. Fred Hofft, a former Purdue man, in conjunction with Mr. A. E. Duram.

At the conclusion of Mr. Donahue's talk Professor Esterline gave a brief explanation of the advantages of Student membership in the Institute. The Purdue Branch has always had a large enrolment, and it is desired to keep up its record.

A business meeting was held on February 16, with a smaller attendance than usual, Mr. J. R. Ong in the chair. The meeting was called to consider an amendment to the constitution of the Branch, and the following amendment was adopted:

"Students of Purdue University who are not enrolled Students of the American Institute of Electrical Engineers may be admitted as local members of this Branch, such Students to be known as Local Members of the Purdue Branch, to have all privileges of the enrolled Students of the Institute except the monthly Institute PROCEEDINGS, and to be admitted upon payment of the local dues."

The report of the committee appointed to consider the matter of space in the Purdue *Annual Debris* of 1909, to be subscribed to by the Branch, was read and accepted. This report recommended the subscription to two pages of space in the journal, and that a suitable heading and a brief history of the Branch be placed on one page with a list of dates, subject, and speaker for each meeting held during the year 1908–1909, the second page to include a list of officers of the Branch and a list of members arranged according to classes.

SAN FRANCISCO SECTION

The San Francisco Section held its regular monthly meeting in the building of the Pacific Gas & Electric Company on February 25, 1909, at which

109 members and visitors were present. It was decided to hold a smoker in April, and an entertainment committee was appointed to arrange the details. A papers committee was also appointed for the purpose of providing papers for meetings, and also a sub-committee to draft a set of by-laws.

Mr. S. B. McLenegan, general manager of the California Central Traction Company, presented a paper entitled " A Talk on the Operating Conditions of the 1200 Volt Railroad System of the California Central Traction Company ", a road operated between Stockton and Lodi, Cal., a distance of about 14 miles. Mr. Lenegan's talk was illustrated by lantern slides. The paper contained many features regarding operating conditions. The author stated that after the trying summer of 1908, which was unusually hot and followed by a very wet winter, especially the month of January, 1909, when the rainfall and floods were very heavy, the road had proved most satisfactory.

SEATTLE SECTION

The Seattle Section has taken possession of its new quarters, the Chamber of Commerce, Central Building, and the first meeting in the new rooms was held on February 20, 1909. The committee on entertainment of visiting engineers announced that it had conferred with a similar body from the Northwest Society of Engineers with a view to joint exercises at the Alaska-Yukon-Pacific Exposition. The exposition officials have tentatively set aside June 10 as A. I. E. E. day at the fair. It was announced that excursion trips to Mt. Ranier, the highest mountain in the United States, and also to the Snoqualmie Falls, were under consideration, as were also steamer trips to Victoria and Vancouver, B. C., or an inspection trip to the Cedar River municipal hydroelectric plant.

The subject of the evening was a paper by Mr. Thomas F. Jack, entitled " Switchboards and Switching for Synchronous Converters." The discussion that followed indicated the interest taken in the paper. For over an hour Mr. Jack discussed with representatives of the hydroelectric companies and other members of the Section the advantages of eliminating fuses, of tying in solid from the transformer-secondaries, of connecting both primary and secondary in delta with cutout switches so that any injured transformer could be quickly removed, and similar kindred subjects in connection with the conversion of high-tension alternating current into low-tension direct. The split-pole converter came in for its share of comment, as did also the converter with synchronous booster. After a brief inspection of the new assembly and committee rooms, the meeting adjourned. Twenty-five members were in attendance.

STANFORD UNIVERSITY BRANCH

At the meeting of this Branch on February 16, 1909, a group picture of the members of the Branch was presented to Professor H. J. Ryan, head of the electrical engineering department. A paper on the " Lincoln Variable-Speed Direct-Current Motor " was read by Mr. H. M. Haver. Mr. W. C. North presented a paper on " Motor Control in General."

SYRACUSE UNIVERSITY BRANCH

This Branch held its regular meeting on February 18, 1909, with Chairman W. P. Graham presiding. There was a total attendance of 23. Professor A. R. Acheson described the testing of a 3750 kw. generator at the Westinghouse works.

The next meeting was held March 4, 1909, at which Mr. E. E. Strong gave a talk on " Engineering Experiences." Mr. Strong made it a point to work each summer in some line which would bring him in contact with practical engineering work. The experiences which he related were of special interest to the senior students. Dr. Graham, Mr. J. P. Barnes, and Mr.

E. C. Sevin took part in the discussion following Mr. Strong's talk.

UNIVERSITY OF TEXAS BRANCH

The regular meeting of the University of Texas Branch was held Friday evening, February 12, 1909, 11 members and one visitor being present. Mr. Romberg spoke on " The Use of the Storage Battery in Connection With Alternating-Current Circuits." In the course of his remarks he described the use of the split-pole synchronous converter in its connection with the subject. Mr. Romberg was followed by Mr. Weaver, who gave a talk on " The Design of Ball Bearings ", showing by means of sketches the different methods used in this work and the relative advantages and disadvantages of each. The remainder of the evening was taken up with the queries in the " Question Box."

The second regular meeting of the month was held on February 26, 1909. The subject discussed was " The Actual Cost of Power Production and Prices Charged to Consumers for the Same." Many points in connection with the production of power by means of water power and producer gas plants were brought out.

TOLEDO SECTION

The March open meeting of the Toledo Section, held in the Builders' Exchange Friday evening, March 5, 1909, was addressed by Mr. M. O. Troy, secretary of the Schenectady Section. Mr. Troy's subject was " Constant Potential Transformers." To permit of economical transmission of power and have electricity in safe condition for use, transformers are built, ranging in capacity from 10 watts to 10,000 kw. and for service from bell ringer work to street railway work. The problems arising as to dissipation of heat were explained. Data of design and how it enters into the cost of operation was discussed, and made clear by means of blackboard explanations. Attention was given to the new silicon-steel. A number of lantern slides were exhibited. In the general discussion which followed, blackboard sketches were used to illustrate proper wiring schemes and showing difficulties caused by certain kinds of grounds in the system. The total attendance numbered 75.

TORONTO SECTION

The members of the Toronto Section had the pleasure of hearing a paper by Mr. H. W. Buck, of New York City, at the regular monthly meeting of the Section held on February 19, 1909. Previously to the meeting a number of the members enjoyed an informal luncheon at the St. Charles Cafe. Mr. Buck's topic was " Some Recent Transmission Line Construction." The paper was illustrated by a large number of lantern slides showing the great variety of recent design in high-tension transmission. A number of various and interesting applications of the new suspended type of insulator were shown. The following men took part in the discussion: Messrs. P. W. Sothman, A. L. Mudge, R. J. Parke, E. Richards Ashworth, E. L. Merrill, and W. A. Bucke.

URBANA SECTION

Professor C. Francis Harding, of Purdue University, was the guest of the Urbana Section at its meeting held February 16, 1909, and 250 members gathered to hear his lecture on " The Design and Construction of a High Speed Railway From a Commercial Standpoint."

WASHINGTON SECTION

The Washington Section adopted a new set of by-laws at its meeting held February 9, 1909, which cover the admission of local members to the Section. The subject for the evening, " Street Lighting ", was presented by Mr. Walter C. Allen, electrical engineer, D. C. Mr. Allen dwelt more especially on the matter of street lighting in the District of Columbia, and outlined the various methods which have been adopted, describing in detail some of the special lighting schemes devised for the Union Station Plaza, Connecticut Avenue Bridge, and other places where special lighting was required. He also described the various methods of street lighting which have been adopted in several foreign cities. A large number of lantern slides served to illustrate the subject.

A special meeting was held on February 26, 1909, to hear a paper by Mr. Percy H. Thomas, consulting engineer, of New York. Mr. Thomas' subject was " The History and Development of Mercury Vapor Apparatus." The meeting was considered the most interesting of the season. Mr. Thomas used both blackboard and lantern slides to illustrate the subject.

WORCESTER POLYTECHNIC INSTITUTE BRANCH

The regular meeting of this Branch was held Friday night, February 12, 1909, in the electrical engineering building, with the usual large attendance, 330 being present. Professor Harold B. Smith, head of the electrical department, delivered an interesting lecture on " High-Potential Power Transmission." The lecture was illustrated by lantern slides showing the development of high-potential power transmission and many of the most prominent installations. The present status of the art was given and its future possibilities outlined. An experimental demonstration of high-voltage phenomena followed the first part of the lecture. In the course of the experiments Professor Smith used a transformer built at the Worcester Polytechnic Institute, capable of giving 200,000 volts. The lecture hall is especially provided with high-voltage outlets from the transformer, which is located in the transformer room directly beneath. This makes it possible to perform high-potential experiments in the lecture room. After the lecture the audience adjourned to the main laboratory where refreshments were served, and the " Tech Orchestra " furnished excellent music for an hour of informal dancing.

At the meeting of the Branch held February 26, 1909, Mr. H. M. Warren, electrical engineer for the Delaware, Lackawanna & Western Railroad Company, spoke on the subject, " Electrical Apparatus in and About Anthracite Coal Mines." Nearly one hundred were present to hear the lecture, which dealt with the mining of coal and its preparation for the market. An outline of the growth in coal mining in the last 10 years was given, and the preparation of coal smaller than chestnut was described. The power plants of the company were spoken of, and its methods employed for raising water were shown. The difficulties encountered and the peculiar requisites of mining apparatus were next taken up, and different motor installations were described. The electric locomotives were also explained. The lecture was illustrated by a large collection of excellent lantern slides.

Assistant Physicist, Bureau of Standards, April 21, 1909

The United States Civil Service Commission announces an examination on April 21, 1909, at the chief cities of the United States, to secure eligibles from which to make certification to fill ten or more vacancies in the positions of laboratory assistant (in physics) and assistant physicist in the Bureau of Standards, at salaries varying from $900 to $1,200 per annum for laboratory assistant, and from $1,400 to $1,800 per annum for assistant physicist, and vacancies requiring similar qualifications as they may occur.

The duties in connection with these positions are similar to those of assistants in the physical laboratories of scientific and technical institutions.

As far as practicable, appointees are assigned to work in the subjects for which they are best fitted.

The examination will consist of the subjects mentioned below, weighted as indicated:

Subjects.	*Weights.*
1. General physics	25
2. Special subjects: (*a*) Advanced general physics, (*b*) theoretical and experimental electricity. Competitors will take one of these special subjects. Subject 2 (*a*), "Advanced general physics," should be taken by competitors for positions in heat and thermometry, weights, and measures, optics, general researches and testing; the subject 2(*b*), "Theoretical and experimental electricity," should be taken by competitors for positions in electricity	25
3. Education and experience (rated on application)	50
Total	100

Applicants must indicate, in answer to question 1 of the application form, the special subject in which they desire to be examined.

Applicants must show in their applications that they have been graduated or are about to be graduated from colleges or technical schools, or that they have attained an equivalent education or training.

Applicants who have not had sufficient education and experience to entitle them to a rating of 70 per cent or more in that subject will not be admitted to the examination.

Two days may be required for this examination.

Age limit, 20 to 35 years on the date of the examination.

This examination is open to all citizens of the United States who comply with the requirements.

This announcement contains all information which is communicated to applicants regarding the scope of the examination, the vacancy or vacancies to be filled, and the qualifications required.

Applicants should at once apply to the United States Civil Service Commission, Washington, D. C., for application Form 1312. No application will be accepted unless properly executed and filed, in complete form, with the Commission at Washington prior to the hour of closing business on April 10 1909. In applying for this examination the exact title as given at the head of this announcement should be used in the application.

Assistant Electrical Engineer

The United States Civil Service Commission announces an examination on April 21, 1909, at all the chief cities of the United States, to secure eligibles from which to make certification to fill a vacancy in the position of assistant electrical engineer, expert in wireless telegraphy, in the Signal Service at Large, at a salary of $1,500 to $1,800 per annum, depending upon the experience and qualifications of the appointee, and vacancies requiring similar qualifications as they may occur in any branch of the service.

The person appointed to the position for which this examination is held will probably be located for the major portion of his time in Washington, D.C., but he will also be required to travel about the United States visiting wireless telegraph stations, which visits may be of a few days or several months' duration.

This examination will consist of the subjects mentioned below, weighted as indicated:

Subject.	*Weight.*
1. Theoretical and practical questions in electrical engineering, with special attention to wireless telegraphy and telephony	50
2. Technical training and experience in the line of the required duties (rated on application)	50
Total	100

Applicants must indicate in their applications that they have a good general knowledge of electrical science and that they are thoroughly familiar with wireless telegraphy and telephony both in theory and operation. Applicants whose applications fail to show that they have had sufficient training and experience to entitle them to a rating of at least 70 per cent in that subject will not be admitted to the examination.

Age limit, 25 years or over on the date of the examination.

This examination is open to all citizens of the United States who comply with the requirements.

This announcement contains all information which is communicated to applicants regarding the scope of the examination, the vacancy or vacancies to be filled, and the qualifications required.

Applicants should at once apply either to the United States Civil Service Commission, Washington, D. C., or to the secretary of the board of examiners at any place mentioned in the list printed hereon, for application Form 1312. No application will be accepted unless properly executed and filed with the Commission at Washington, prior to the hour of closing business on April 10, 1909. In applying for this examination the exact title as given at the head of this announcement should be used in the application.

Issued March 11, 1909.

John Fritz Medal

A meeting of members of the four national engineering societies will be held in the Engineers' Building, New York, April 13, 1909 at 8 o'clock p.m. for the presentation of the John Fritz Medal to Mr. Charles T. Porter, by Mr. Henry R. Towne, president of the John Fritz Medal Board of Award. There will be addresses by Frank J. Sprague in behalf of the electrical engineers, and also by representatives of other branches of the engineering profession.

Personal

MR. I. E. BLUMGARDT has changed his address temporarily to Mt. Vernon, Indiana, where he is recovering from the effects of a street railway accident.

MR. E. D. MEYER has taken over the superintendency and management of the McPherson Water & Electric Department, McPherson, Kansas.

MR. H. S. DELANCIE has been transferred from the Philadelphia to the San Francisco office of the Westinghouse Electric & Manufacturing Company.

MR. C. R. BEARDSLEY is at present located in the New Haven office of the General Electric Company. His address is Malley Building, New Haven, Conn.

MR. S. L. E. ROSE, of the illuminating engineering department of the General Electric Company, has been transferred from the Lynn works to the Schenectady works.

MR. G. PARSONS has severed his connection with The Smith Improved Lock Nut Company to take a position with the Westinghouse Lamp Company at Bloomfield, N. J.

MR. E. N. HYDE, formerly with the Frank H. Stewart Electric Company, Philadelphia, Pa., has accepted a position in the sales department of the Holophane Company, 227 Fulton St., New York.

MR. N. R. STANSEL, engineering inspector, has been transferred from Omaha, Neb., to Washington, D. C. His headquarters are in the office of the Supervising Architect, U. S. Treasury Department.

MR. K. R. OGDEN is at present located at Tarentum, Pa., as district plant chief of the Central District and

Printing Telegraph Company. He has held his present position since October 15, 1908.

Mr. Ralph A. Watson, until lately superintendent for Compania Hidroelectrica é Industrial de Teziutlán, S. A., has become a member of the firm of Watson & Dey, engineers and contractors, Mexico City.

Mr. A. E. Wood, formerly with the Trumbull Electric Manufacturing Company, is at present located in Seattle, Washington, engaged in construction work for the Northern Pacific Irrigation Company.

Mr. E. N. Sweitzer, chief electrician, U. S. Navy, who has been stationed at the Bremerton Navy Yard, Washington, has been ordered to the navy gun factory, Washington, D. C., for instruction in ordnance.

Mr. O. S. Clements, formerly in charge of electric light plants at Colon, for the Panama Railroad Company, has been appointed superintendent of the Eastport Electric Light Company, Eastport, Maine.

Mr. William E. Hodge, formerly in the engineering department of the New England Tel. & Tel. Company, Boston, has been transferred to Springfield, Mass., as cable tester for the western division of the same company.

Mr. L. L. Perry, for some years employed as electrical engineer by Mr. F. S. Pearson, has resigned his position. Mr. Perry has devoted his time largely to hydroelectric power house and transmission line work.

Mr. J. E. Wickstrom, who has been with the Seattle-Tacoma Power Company, Seattle, Washington, for the past two years, has opened an office in the Central Building, Seattle, as consulting engineer.

Mr. Cooper Anderson was appointed on February 1, 1909, superintendent of operation for the Telluride Power Company in Utah and Idaho, in addition to his former duties with the same company in Colorado.

Sir Robert Hadfield, of London, was one of the guests and speakers at the biennial dinner of the Sheffield Society of Engineers and Metallurgists, held at the Royal Victoria Hotel, Sheffield, on Friday, February 26.

Mr. E. S. Harrar, until recently electrical engineer for the Pennsylvania & Lake Erie Dock Company, at Fairport Harbor, Ohio, is now associated in a similar capacity with the Pittsburg & Conneaut Dock Company, Ashtabula Harbor, Ohio.

Mr. William P. Abendroth has been retained as electrical and mechanical engineer for Abendroth Bros., at their foundries. He was formerly connected with the engineering department of the General Railway Signal Company of Rochester, N. Y.

Mr. A. H. Ackermann, formerly sales engineer of the Studebaker Company of New York, has been appointed manager of the New York office of the National Battery Company, with headquarters at 527 Fifth Avenue, New York City.

Mr. A. J. J. Pfeiffer has given up the position of manager and chief engineer of the Calcutta Tramways Company, and has opened up an office as consulting engineer at Broad Street House, New Broad Street, London, E. C., England.

Mr. Hugo Fuchs, having severed his connection with the New York Central & Hudson River Railroad Company, is now engaged as consulting engineer in Budapest, Hungary. His address is V Lipot Boulevard 27, Budapest.

Mr. Frank J. Petura, formerly with the Denver Gas & Electric Company, has been transferred to the New York office of Henry L. Doherty & Company, 60 Wall Street, New York, where he will be connected with the engineering department.

Mr. Percy H. Thomas, consulting engineer of New York City, gave an illustrated paper before the officers stationed at the United States Engineer School at Washington Barracks, on February 26. A large number of military engineers were present.

Dr. Samuel Sheldon, accompanied by his wife and son, has gone abroad for the benefit of his health. He sailed March 6 on the Prinzess Irene, arriving in Naples March 19. He will visit Italy, France, Switzerland and Germany, remaining abroad until August.

Mr. J. L. Longino, who has recently completed preliminary surveys on an interurban road in southwest Texas for Dixon and Smith, consulting engineers of St. Louis, Mo., has identified himself with their St. Louis office, 818–20 Wright Building.

Mr. Guion Thompson, recently engaged in the development of the Litchfield Electric Light & Power Company's hydroelectric transmission plant, Litchfield, Conn., has entered the engineering department of the American Brass Company, Waterbury, Conn.

Mr. Harry P. Freund and Mr. Wallace M. Hyman have become members of Reis & O'Donovan, Inc., 207 East 37th Street, New York. Mr. Freund has been with this company for some years. Mr. Hyman has been associated with P. R. Moses, consulting engineer.

Mr. Albert B. Herrick, consulting electrical engineer has moved his office from 120 Liberty Street to 14 and 16 Church Street, corner of Cortlandt, New York City, where he has also combined his laboratory and testing room on the same floor with his office.

Mr. Robert Hawxhurst, Jr., M., A.S.C.E., M., A.I.M.E., A., A.I.E.E., remains in Chile, S. A., as general manager of the Poderosa Mining Company, Limited, of London, which company has acquired the properties of The Compania Minera Poderosa de Collahuasi de Chile.

Dr. Berthold Monasch, who for the past five years was associated with the arc lamp department of the Allgemeine Elektrisitats Gesellschaft, Berlin, is now connected with the Wolfrumlampen A. G. Augsburg (Germany) as superintendent. Private address, Augsburg, Prinzregentenstr. 9.

Mr. Norman McD. Crawford, formerly general manager of the Hartford Street Railway Company, and later vice-president of the Ohio Electric Railway Company, was elected president of the Mahoning and Shenango Railway & Light Company on November 30, 1908, and is now located at Youngstown, Ohio.

Mr. L. D. Hitzeroth has tendered his resignation as electrical engineer of the Century Electric Construction Company, 18 Tell Street, San Francisco, to accept a position as superintendent of power houses for the Nevada-California Power Company, at Bishop, Inyo County, Cal.

Mr. F. R. Fishback, who was with the sales department of the Electric Controller & Manufacturing Company, Cleveland, O., has been appointed manager of the New York office of that Company, with headquarters at the Hudson Terminal Building, 50 Church Street, New York City.

Mr. William Elsdon-Dew, who for 13 years was chief engineer to the

Transvaal G. M. Estates at Pilgrims' Rest, and associated with them in all of their hydraulic power schemes, now occupies the position of chief engineer to the Witwatersrand Deep, Limited, Knights, Transvaal, South Africa.

Mr. Charles D. Richardson has resigned as engineer of the Pittsburg office of the Underwriters' laboratories to become assistant electrical engineer in the inspection department of the Associated Factory Mutual Fire Insurance Companies, 31 Milk Street, Boston.

Mr. James H. Habberly has resigned his position with the Fort Wayne Electric Works to become secretary and treasurer of the Fort Wayne Engineering & Manufacturing Company, Fort Wayne, manufacturers of condensers, electrically-driven air compressors, house-pumps and automatic valves.

Mr. Lawrence Whittredge Cady has been appointed chief electrical engineer of the Browning Engineering Company. Mr. Cady has been engaged in redesigning the motors, generators and lift magnets of the above named company, and is located in the main office at Cleveland, Ohio.

Mr. C. I. Hickman, who held a position in the laboratory of the Western Electric Company, New York City, and later was in the repair department of the Chicago Telephone Company, has resigned the latter position to accept one as salesman with the western office of the Holtzer-Cabot Electric Company, Chicago.

Mr. S. A. Spalding has recently resigned his position as superintendent of power, Brooklyn Rapid Transit Company, and accepted a position in the electrical department of the Pennsylvania Tunnel & Terminal Railroad Company, 10 Bridge Street, New York City, under Mr. George Gibbs, chief engineer of electric traction.

Mr. B. A. Behrend, for nine years chief engineer of the Bullock Electric Manufacturing Company, and for five years chief electrical engineer and consulting engineer of the Allis-Chalmers Company, whose electrical department he organized, is now with the Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa., in an advisory capacity.

Mr. J. Robert McFarlin, for the past two years electrical engineer of the Garton-Daniels department of the Electric Service Supplies Company, has been transferred from the engineering department in Keokuk, Iowa, to the sales department in Philadelphia, where he will engage in work as special engineering representative.

Mr. W. Vincent Treeby has severed his connection with Messrs. Richardson's Westgarth & Company, Ltd., Hartlepool, to take a position as mechanical and electrical designing engineer to Messrs. W. T. Towler & Son, Ltd., engineers & boilermakers, Carpenter Road, Stratford, London, England. Mr. Treeby assumed his new duties on November 20, 1908.

Mr. Justus B. Entz, formerly chief engineer of the Electric Storage Battery Company, of Philadelphia, and later first vice president of the Electric Vehicle Company of Hartford, Conn., has opened an office as consulting engineer, with headquarters at the West End Trust Building, 32 South Broad Street, Philadelphia, Pa.

Mr. Charles E. Carter has given up his position as superintendent of the Madison Gas & Electric Company, Madison, Wis., and is now superintendent of distribution and electrical engineer for the Northern Colorado Power Company, Denver, Colo. This company operates in the northern part of

Colorado and southern part of Wyoming.

Mr. F. T. Wright, who for the past three years has been electrical engineer in charge of train lighting, for the Southeastern & Chatham Railway Company, London, England, has left that company to join the South Indian Railway Company as assistant carriage and wagon superintendent. His address is: South Indian Railway Company, Negapatam, Madras, India.

Mr. Francis J. White recently resigned his position as battery engineer of the New York Central & Hudson River Railroad Company and accepted a position in the electrical department of the Pennsylvania Tunnel & Terminal Railroad Company, 10 Bridge Street, New York City, under Mr. George Gibbs, chief engineer of electric traction.

Mr. Charles O. Collett, for the past year mechanical engineer in the railway construction department of the Westinghouse Electric and Manufacturing Company, Stamford, Conn., which was headquarters for the electrification of the New York, New Haven & Hartford Railroad, has been transferred to the railway engineering department of the same company at East Pittsburg, Pa.

Mr. Charles H. Wright, lately district manager at Ottawa, Ontario, for the Canadian General Electric Company, has been appointed district manager for the same company, at Halifax, N. S., controlling the maritime provinces and Newfoundland. Mr. Wright has been with this company for many years in various engineering and business positions.

Mr. Henry C. Eddy, who for the past eight years has been western district manager for the American District Steam Company of Lockport, N. Y., resigned his position with that company on January 15, 1909, to engage in the bond business, under his own name. Mr. Eddy has been identified with electric railway and light companies since 1889. He will make a specialty of marketing the securities of public service corporations.

Mr. A. W. McLimont has resigned as electrical engineer of the Public Service Commission, New York, to accept the appointment of general manager of the Chicago & Milwaukee Electric Railway Company, Highwood, Ill. Mr. McLimont directed one of the most important undertakings of the commission, being chairman of the committee which conducted the tests of car fenders and wheel guards.

Mr. O. G. Petersen, for the past six years electrical and mechanical engineer for the Stearns Coal Company, the Kentucky and Tennessee Railway, and the Stearns Lumber Company, all of Kentucky, has severed his connection with these companies and is now president of the Associated Engineering Company of Louisville, Ky., a corporation formed to engage in consulting, designing and constructing engineering work.

Mr. K. McCaskill, who for the last two and a half years was in the electrical engineering department of the New York Central & Hudson River Railroad Company, engaged in the electrification of the terminal in and about New York City, is now in the service of the Southern Pacific Railroad in the electrification of their suburban branches in Oakland, Alameda and Berkeley. His work is in connection with transmission, distribution and catenary construction.

Mr. W. W. Moore, former manager of the engineering department of The Wesco Supply Company, of St. Louis, Mo., is now in charge of the new branch of this company, at 20 South 20th Street, Birmingham, Ala., where they have a large stock of electrical supplies and machinery. Mr. Moore states that there are now twenty-one Associates of the A.I.E.E. located at Birmingham, and they hope to be able to secure enough additional members to establish a Section there in the very near future.

MR. HENRY FLOY, consulting electrical and mechanical engineer, 165 Broadway New York, is the author of a book on "High-Tension Underground Cables," published by the Electrical Publishing Company, 165 Broadway. The book treats of insualtion and construction of high-tension cables, the use of same, with operating records, a valuable table of 35 different installations, giving miles of cable in use, voltage used whether operated with grounded neutral, character and thickness of insulation, and other details. It contains also formulas for use in cable calculations.

MR. EUGBN EICHEL, consulting engineer, of Berlin, formerly in the engineering department of the General Electric Company has accepted the position of editor of the electric transmission and traction paper: "*Elektrische Kraftbetriebe & Bahnen*" published at Munich.

At the February meeting of the Dresdener Elektrotechnische Verein, Mr. Eugen Eichel read a paper entitled "American Electric Railways." Special attention was paid to the electrified trunk lines terminating at New York. The chairman, Director Heubach spoke of the indebtedness of the engineering profession to Mr. W. S. Murray, for his open-hearted manner in furthering the progress of railroad electrification by freely discussing the difficulties attending installation and operation, their causes and remedies.

Among the engineers present were Director Hofmeister, Captain Sickel, Director General von Kirchbach, as representatives of the Royal Saxonien War Ministry and the Government Railroad, also Professor Görges, one of the earliest investigators of the single phase series motor and Professor Kübler of the Royal Technical University, Dresden.

Obituary

MAJOR EDMUND LOUIS GRAY ZALINSKI, U. S. A., retired, widely known in military circles, and a veteran of the A. I. E. E., died of pneumonia at the New York Hospital on Wednesday, March 10, after an illness of several weeks. Major Zalinski was taken ill last January, and about the middle of that month was admitted to the hospital. He was born in Kurnich, Prussian Poland, December 13, 1849. His parents came to this country when he was four years of age, and settled at Seneca Falls, N. Y. When the civil war broke out he was attending the Syracuse High School, and it was during that period that he conceived the idea of a military career. Owing to his youth he was obliged to continue at school for the first few years of the war, when he was brought to the attention of General Miles, who took him on his staff as an aide. At the close of the war he was given a commission as second lieutenant of artillery in the regular service, and two years later advanced to the grade of first lieutenant. In 1887 he became captain. On May 17 of the same year he was elected to membership in the Institute as an Associate. During the interim he was stationed at various forts along the Atlantic Coast, besides serving for three and a-half years as professor of military science at the Massachusetts Institute of Technology. Major Zalinski was also an inventor, having developed and perfected a number of appliances which were subsequently adopted for coast defence. In 1883 Robert T. Lincoln, then secretary of war, detailed him to investigate the possibility of discharging a dynamite torpedo from a pneumatic gun, and as a result of his experiments, which continued until 1889, the principles he laid down were incorporated in the dynamite cruiser Vesuvius. Among his inventions were an intrenching tool, a ramrod bayonet, and a telescopic sight for long-range guns. He also developed a system of range and position finding. A slight stroke of paralysis influenced him to retire from active service in 1894. In 1904 he was promoted to the rank of major on the retired list. After his retirement, he devoted some years to the study of illuminating engineering. The Zalinski type of diffusing reflectors are now generally accepted and used throughout this and other countries. During the latter part of July, 1908 he was elected president of the Bureau of Illuminating Engineering, 437 Fifth Avenue, New York, which office he held to the time of his death.

His remains were interred with military honors, at Rochester, N. Y., on Sunday, March 13. He is survived by one son, Edmund Robbins Zalinski.

Congress of International Association for Testing Materials

The Fifth Congress of the International Association for testing materials, will be held in Copenhagen, September 7 to 11, 1909. The Institute has been invited to appoint delegates to the Congress. Members of the Institute who expect to be in Copenhagen on the dates specified, are requested to notify the secretary of the Institute, so that a list of members who expect to be present may be forwarded to the officials of the Congress.

Accessions to the Library

The following accessions have been made to the Library of the Institute since the last acknowledgment:

Alternating Current Phenomena. By C. P. Steinmetz. Edition 4. New York, McGraw Publishing Company. $4.00 net (Gift of publishers).

CONTENTS.—Chapter I.—Introduction. II.—Instantaneous and Integral Values. III.—Law of Electro-magnetic Induction. IV.—Graphic Representation. V.—Symbolic Method. VI.—Topographic Method. VII.—Admittance, Conductance, Susceptance. VIII.—Circuits Containing Resistance, Inductance and Capacity. IX.—Resistance and Reactance of Transmission Lines. X.—Effective Resistance and Reactance. XI.—Foucault or Eddy Currents. XII.—Power and Double Frequency Quantities in General. XIII.—Distribution Capacity, Inductance, Resistance and Leakage. XIV.—The Alternating-Current Transformer. XV.—General Alternating-Current Transformer or Frequency Converter. XVI.—Induction Machines. XVII.—Alternate-Current Generator, XVIII.—Synhcronizing Alternators. XIX.—Synchronous Motor. XX.—Commutator Motors. XXI.—Reaction Machines. XXII.—Distortion of Wave-Shape and Its Causes. XXIII.—Effects of Higher Harmonics. XXIV.—Symbolic Representation of General Alternating Waves. XXV.—General Polyphase Systems. XXVI.—Symmetrical Polyphase Systems. XXVII.—Balanced and Unbalanced Polyphase Systems. XXVIII.—Interlinked Polyphase Systems. XXIX.—Transformation of Polyphase Systems. XXX.—Copper Efficiency of Systems. XXXI.—Three-Phase System. XXXII.—Two-Phase System. Appendices.—I.—Algebra of Complex Imaginary Quantities. II.—Oscillating Currents.

Annual Report of the Boston Transit Commission. 14th Boston, E. W. Doyle, 1909. (Gift.)

Annual Report of the Connecticut Railroad Commissioner, 24th, 26th–31st, 33d–43d, 48th. Hartford, 1877–1895, 1900. (Purchase.)

Annual Report of the Interstate Commerce Commission. 1st–9th. Washington, U. S. Government, 1887–1895. (Purchase.)

Annual Report of the Iowa Board of Railroad Commissioners. 1st–26th. Des Moines, 1878–1904. (Purchase)

Annual Report of the Kansas Board of Railroad Commissioners 1st, 3rd, 5th–14th. Topeka, 1884–1896. (Purchase.)

Annual Report of the Maine Railroad Commissioner. 33d, 34th, 39th–40th, 42d–45th, 47th. Augusta, 1892–1905. (Purchase.)

Annual Report of the State Forester of Massachusetts 5th, 1908. Boston, Wright & Potter Printing Co., 1909. (Gift of Massachusetts State Forester.)

Arguments of Robert M. Morse, Jr. Samuel C. Darling and J. W. Hammond before the Committee on Street Railways of the Massachusetts Legislature of 1882 in aid of the petition of the Charles River Street Railway Company for Certain Legislation. Boston, J. A. Cummings, & Co., 1882. (Purchase.)

The Bell Telephone. The Deposition of Alexander Graham Bell in the Suit Brought by the United States to Annul the Bell Patents. Boston, American Bell Telephone Co., 1908. (Gift of A. G. Bell.)

Charters and Locations of the Several Street Railways in the City of Boston, 1869. Boston, A. Mudge & Son, 1869. (Purchase.)

Currents of High Potential of High and Other Frequencies by W. B. Snow. New York, Scientific Authors' Publishing Co., 1905. (Gift of author.)

Earth's Magnetism, Principal facts of and method of determining the true Meridian and the Magnetic Declination. By the United Coast and Geodetic Survey. Washington, U. S. Government, 1909. (exchange.)

Electric Arc Lamps. By J. Zeidler & J. Lustgarten. New York, Van Nostrand Company, 1908. $2.00.

Electrical Traction. By Ernest Wilson & Francis Lydell. 2 vols. London, Arnold, n. d. $3.00 net.

A few Facts About Incandescent Lighting. no place no date. (Gift of Carl Hering.)

General Laws Relating to Street Railway Companies of Massachusetts Boston, 1897. (Purchase.)

Hydro-Electric Power Plant of the Inland Empire System Spokane-Washington, no place no date. (Gift of Sanderson and Porter.)

Hydro-Electric Practice. A Practical Manual on the Development of water power, by H. A. E. C. von Schon. Philadelphia, Lippincott Co. 1908. $6.00 net.

Index to Subjects Covered in the Printed Records of the National Fire Protection Association. January, 1909. Chicago, 1909. (Exchange.)

Isolated Plant published by the Isolated Plant Publishing Co., Volume 1, No. 1. December, 1908.

"This publication will be the organ of isolated plant interests and questions affecting installation or operation of plants will be discussed and presented. It will present data of comparative costs of central station service in figures of operating costs from buildings where plants are installed and also from buildings obtaining service from Central service companies."

Journal of the Royal Microscopical Society. February-December, 1908 Numbers 1–6. London, Williams & Norgate, 1908. (Gift of McGraw Publishing Company.)

Law and Business of Engineering and Contracting. By C. E. Fowler. New York, McGraw Publishing Company, 1909. Price $2.50 net (Gift of Publishers.)

CONTENTS.—Chapter I.—The relation between the engineer and contractor. II.—Ordinary forms of contracts. III.—Ordinary Specifications. IV.—Special forms of specifications. V.—Special forms of contracts. VI.—Inspection of Engineering work. VII.—Estimating materials and the cost of engineering structures. VIII.—Bidding on engineering work. IX.—Organization of contract work. X.—Essentials of contract law.

Librarian's Report of Cornell University. 1907–1908. Ithaca, 1908. (Gift.)

Model Engineer and Electrician. weekly volume 20–date. London, 1909-date. (Purchase.)

Nature, weekly. volume 79-date. London, 1909-date. (Purchase.)

Official Catalogue Exhibition of the German Empire. International Exposition St. Louis, 1904. Berlin, 1904. (Gift of Dr. W. H. Tolman.)

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Power and energy of the complex circuit. VIII. —Reflection and refraction at transition point. IX.—Inductive discharges.

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Vol. XXVIII **May, 1909** No. 5

Annual Meeting, New York May 18, 1909

The annual meeting will be held in New York City on Tuesday, May 18, 1909. At this meeting the Board of Directors will present its report for the fiscal year. The reports of all officers and of the standing committees will also be presented, and the vote for officers of the Institute for the ensuing administration year will be announced.

In addition to the reports and regular business of the meeting a paper entitled "The Patent System in its Relation to Industrial Development" will be presented by Mr. Frederick P. Fish, formerly president of the American Telegraph and Telephone Company and now of the law firm of Fish, Richardson, Herrick and Neave, of Boston. This paper appears in full in Section II.

Annual Convention

The next annual convention will be held at Hotel Frontenac. Thousand Islands, Frontenac, New York, beginning Monday, June 28, 1909. A tentative list of the papers to be presented is as follows:

1. Some Considerations in Designing Heavy Capacity Fuses. By L. W. Downes.
2. A Sketch of the Theory of the Adjustable Speed Single-phase Shunt Induction Motor. By F. Creedy.
3. Calculation of the High-Tension By Percy H. Thomas.
4. Transmission Paper. By W. S. Moody.
5. Effect of Frequency upon the Cost of Alternators. By C. J. Fechheimer.
7. Two papers on high-tension transmission subjects. By R. D. Mershon.
8. The Reduction in Capacity of Induction Motors due to Unbalancing in Voltage. By S. B. Charters and W. A. Hillebrand.
9. The Heating of Induction Motors. By Alexander M. Gray.
10. Telephone paper. By J. J. Carty.
13. Three Industrial power papers. By D. B. Rushmore.
15. The Resistance and Reactance of Armored Cables. By J. B. Whitehead.
17. Two Educational papers. By A. S. Langsdorf and H. J. Ryan.
18. Generation for 100,000 Cycles. By E. F. Alexanderson.
19. Repulsion Motors with Variable-Speed Shunt Characteristics. By E. F. Alexanderson.
20. Auxiliary Poles for Direct-current Machines. By John N. Dodd.
21. The Thermal Convection from Thin Copper Wire Supported in Air. By A. E. Kennelly, C. A. Wright and J. S. Bylevelt.
23. Two papers. By Comfort A. Adams.
24. Harmonics, Even and Odd. By J. B. Taylor.
25. Electric Measuring Devices. By L. T. Robinson.

Industrial Education Meeting

A special meeting of the Institute, devoted to a discussion of Industrial Education was held in the Engineers Building, 33 West 39th Street, New York, April 16. The meeting was planned by the Educational Committee, of which Professor H. H. Norris of Cornell University is chairman. Vice-President James G. White presided, and the attendance was 125. Messrs. Scott, Steinmetz and Mailloux, of the committee, were present. The paper of the evening was by Dean Herman Schneider of the University of Cincinnati, and was printed in the April issue of the PROCEEDINGS. The discussion was by Messrs. Harry Barker, G. M. Basford, A. D. Dean, F. Phillips, C. R. Dooley, C. E. Downton, S. W. Ashe, C. F. Scott, and C. P. Steinmetz.

John Fritz Medal Meeting

A joint meeting of the three founder societies and the American Society of Civil Engineers was held in the auditorium of the Engineers Building, 33 West 39th Street, New York, March 24, 1909, for the purpose of awarding the John Fritz Medal to Mr. Charles T. Porter, Honorary Member of the American Society of Mechanical Engineers. The honor was conferred on Mr. Porter for meritorious service in the advancement of steam engineering and improvements in engine construction, and the medal was presented by Mr. Edmund G. Spilsbury, chairman of the John Fritz Medal Board of Award. Four addresses were made: " The Debt of Modern Industrial Civilization to the Steam Engine as a Source of Power " by Dean W. F. M. Goss, University of Illinois; " The Debt of the Modern Steam Engine to Charles T. Porter ", by Professor F. R. Hutton, of New York City; " The Debt of the Era of Steel to the High-Speed Steam Engine", by Robert W. Hunt, of Chicago; " The Debt of the Era of Electricity to the High-Speed Steam Engine ", by Frank J. Sprague, of New York. In the past the medal has been bestowed upon Lord Kelvin, George Westinghouse, Alexander Graham Bell, and Thomas A. Edison.

The Conservation Meeting

The joint meeting of the four national engineering societies announced in the March PROCEEDINGS was held in the Engineers Building, New York, March 24, and was attended by 625 people, mostly engineers. In the absence of President Bates of the American Society of Civil Engineers, Past President James Douglas of the American Institute of Mining Engineers officiated as chairman. The paper presented by Lewis B. Stillwell Mem. A.I.E.E. on " Electricity and the Conservation of Energy " is printed in Section II of this issue. The four papers read are now being printed in a single pamphlet under the supervision of Charles Warren Hunt, Secretary of the American Society of Civil Engineers. The price of the pamphlet has not yet been fixed, but orders for copies may be sent to the secretaries of any of the societies.

Spring Meeting of the American Society of Mechanical Engineers, Washington, D.C.

The American Society of Mechanical Engineers holds its Spring Meeting in Washington, D. C., May 4–7. Professional sessions will be held at which papers on the conveying of materials, gas-power engineering, steam turbines, the specific volume of saturated steam, oil well pumping, and various other subjects, will be discussed.

At the reception, which will be held in the New Willard Hotel, an address of welcome will be made by the Hon. B. F. Macfarland, President of the Board of District Commissioners, with a response by Mr. Jesse M. Smith, president of the society.

During the Convention President Taft will hold a reception for the members, at the White House. The War Department will give a special exhibition drill of the U. S. troops at Fort Myer, to which the members and guests will be invited. At the same time, if the conditions are favorable, an ascension of a dirigible balloon will be made and probably also that of an aeroplane.

An address will be given by Rear Admiral Melville, retired, past-president of the society, and former engineer-in-chief of the navy, the subject being " The Engineer in the Navy." This session will be made the occasion for the presentation of the National Gallery of a portrait of Rear Admiral Melville, presented by friends and admirers. It will be received for the National Gallery by Dr. C. D. Walcott, Secretary of the Smithsonian Institution.

F. H. Newell, Director of the Reclamation Service will deliver an illustrated address on " Home Making in the Arid Regions." Trips will be made to various points of interest about the city and a number of pleasurable excursions have been planned.

The papers to be presented are as follows:

A Unique Belt Conveyor, Ellis C. Soper.
Automatic Feeders for Handling Material in Bulk, C. Kemble Baldwin.
A New Transmission Dynamometer, Prof. Wm. H. Kenerson.
Polishing Metals for Examination with the Microscope, A. Kingsbury.
Marine Producer Gas Power, C. L. Straub.
Operating System for a Small Producer Gas Power Plant, C. W. Obert.
A Method of Improving the Efficiency of Gas Engines, T. E. Butterfield.
Offsetting Cylinders in Single-Acting Engines, Prof. T. M. Phetteplace.
Small Steam Turbines, Geo. A. Orrok.
Oil Well Tests, Edmund M. Ivens.
Safety Valve Discussion.
Specific Volume of Saturated Steam, Prof. C. H. Peabody.
Some Properties of Steam, Prof. R. C. H. Peck.
A New Departure in Flexible Staybolts, H. V. Wille.

Minutes of April Meeting of the Institute

The two hundred and thirty-sixth meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineers Building, 33 West 39th Street, New York City, Friday, April 9, 1909. In the absence of President Ferguson, Senior Vice-President J. G. White presided, and called the meeting to order at 8 p.m. The Secretary announced that at the meeting of the Board of Directors held during the afternoon 105 Associates were elected. The directors present at the meeting were:

Past-president Henry G. Stott, New York; Vice-presidents James G. White, New York, Calvert Townley, New Haven, Conn.; Managers Paul M. Lincoln, Pittsburgh, Pa., William S. Murray, New Haven, Conn., P. H. Thomas, New York, David B. Rushmore, Schenectady, N. Y., W. G. Carlton, New York, Charles W. Stone, Schenectady, N. Y., H. E. Clifford, Boston, Mass.; Treasurer George A. Hamilton, New York; Secretary Ralph W. Pope, New York.

The Associates elected were as follows:

ANTOINE, LAWRENCE M., Supt., Maintenance & Operation, Home Telephone Co., Portland, Oregon.
ATWATER, GEORGE FRANKLIN, Student, Sheffield Scientific School; res., 1776 State St., New Haven, Conn.
BALL, SUMTER MAYS, 47 East 10th Street, Atlanta, Ga.
BARBER, HERBERT CAMPBELL, Assistant, City Electrical Department; res., 51 Elm Ave., Toronto, Ontario.
BARTHOLOMEW, HAROLD CRISWELL, Instructor in Electrical Engineering, University of Pennsylvania, Philadelphia, Pa.
BAYLOR, NORMAN R., Inspector in Meter Dept., San Francisco Gas & Electric Co.; res., 138 23rd Ave., San Francisco, Cal.
BEAN, CONDON ROY, Travelling Salesman, John A. Roebling's Sons Co.; res., 91 1st Street, Portland, Ore.

Bleckwedel, George Henry, General Tester, Brooklyn Edison Co.; res., 1268 Madison St., Brooklyn, N. Y.

Bosch, Henry, Draughtsman, Pacific Gas & Electric Co.; res., 902 Eddy St., San Francisco, Cal.

Breese, John Elmer, Telephone Installer, Central Union Telephone Co.; res., 226 S. West St., Lima, Ohio.

Bryant, Roy Blake, 1104 Elm Street, Little Rock, Arkansas.

Burghduff, Alonzo E., Switchboard Manager, Home Telephone Co.; res., 290 E. 40th St., Portland, Ore.

Burnett, Arthur Hardin, Supt., South Tower Power Division, Pacific Gas & Electric Co., Richmond, Cal.

Burns, Archibald Eugene, Wire Chief, Northwestern Long Distance Tel Co.; res., 409 Sacramento St., Portland, Ore.

Buswell, James Morgan, Construction Man, General Electric Co., San Francisco; res., 646 54th St., Oakland, Cal.

Cadwell, Ralph Lindel, Superintendent, The Warren-Bisbee Railway, Warren, Arizona.

Cargill, Walter Neal, Supt. of Power Stations, Boston & Northern St. Ry. Co.; res., 48 Hamilton Ave., Lynn, Mass.

Christie, William Frank, Pietermaritzburg, Natal, South Africa

Clark, James Russell, Superintendent's Clerk, Western Electric Co., Hawthorne; res., 2325 State St., Fl. 21, Chicago, Ill.

Clark, Paul Loveridge, Electrical Draftsman & Engineer, with L. B. Stillwell, 1314 Continental Bldg., Baltimore, Md.

Cole, Charles Danolds, Construction Engineer, Rice Lake Milling & Power Co.; res., Ross Hotel, Rice Lake, Wis.

Crawford, Perry O., Electrical Engineer, Northern California Power Co., Manton, Cal.

Crouse, David Eldridge, Asst. to Electrical Engineer, Maryland Electric Railways; res., 139 Charles St., Annapolis, Md.

Cullinane, Peter Francis, Chief Engineer, United States Treasury Dept., Custom House, New Orleans, La.

Curtis, Harry L., Electrical Engineer, Minnesota & Ontario Power Co., International Falls, Minn.

Danielson, Wilmot A., 2nd Lieutenant Coast Artillery Corps, United States Army, Fort Worden, Wash.

Dawes, Lyman Miner, Electrician, Trenton Shops, Pennsylvania Railroad; res., 20 Wall St., Trenton, N. J.

Eakins, Arthur Albert, Electrician, Quartermaster's Department, United States Army, Governor's Island, N.Y.

Edwards, Jesse Boland, Professor of Physics, Georgia School of Technology Atlanta, Ga.

Egg-Sieberg, Hart, Chief Engineer of Railway Dept., The Alioth Electric Co.; res., Guterstrasse 229, Bale, Switzerland.

Eliot, Edward Munroe, Electrical Draftsman, Portland Railway Light & Power Co., Portland, Ore.

Fink, Howard, Superintendent and Secretary, John E. Graybell & Co., Inc;. res., 104 East Market St., York, Pa.

Flagg, Lester L., Power House Foreman, Pacific Gas & Electric Co., San Francisco; res., Electra, Cal.

Frazer, Harry W., Chief Electrician, Chas. Warner Co.; res., 1211 King Street, Wilmington, Del.

Friendly, Herbert M., Superintendent & Engineer, Northwestern Long Distance Telephone Co.; res., 223 No. 21st St., Portland, Ore.

Fulton, Robert Niven, 2d Operating Engineer, The Dunedin Corporation; res., 50 Manor Place, Dunedin, N. Z.

Fynn, Valere Alfred, Consulting Engineer, Usona Hotel, King's Highway, St. Louis, Mo.

Gale, Walter, Jr., Electrical Inspector, Philadelphia Fire Underwriters' Assn.; res., 623 Vine Street, Philadelphia, Pa.

Gaskin, Ivan Henry, Chief Electrician, Gillette Safety Razor Co., Boston; res., 54 King Street, Dorchester, Mass.

Gent, Rufus, Chief Electrician, The United Engineering & Contracting Co., 32 East 33rd St., New York City.

Glynn, Charles Victor, Mechanical & Electrical Engineer, Hershey Chocolate Co., Hershey, Pa.

GULDEMEISTER, OTTO P., Instructor of Applied Electricity, Portland School of Trades, 11th & Davis Sts., Portland, Ore.

HALL, CHARLES ELLSWORTH, General Superintendent, Iowa Telephone Co.; res., 1118 W. 26th St., Des Moines, Iowa.

HAMILTON, FRED G., Superintendent Western Division, Mt. Whitney Power Co., Visalia, Cal.

HAMILTON, TABER, Master Mechanic, The Cumberland Valley Railroad Co., Chambersburg, Pa.

HAMILTON, WILLIAM MUNROE, Illuminating Engineer, Portland Railway, Light & Power Co.; res., 242 Grant St., Portland, Ore.

HARLEY, EMERSON BRYANT, Draughtsman, Portland Railway, Light & Power Co.; res., 295 10th St., Portland, Ore.

HASKELL, DELBERT, Electrical Engineer, Vantanas Mining & Exp. Co., Vantanas, Durango, Mexico.

HAYES, GLENN BURR, Assistant Engineer, Leamington Light & Heat Co., Ltd., Leamington, Ont.; res., 26 E. High St., Detroit, Mich.

HAZELTON, HUGH, Electrical Engineer with L. B. Stillwell, 100 Broadway, New York City.

HERSHEY, HENRY BONNER, Resident Engineer, Ford, Bacon & Davis; res., 522 West 145th St., New York City.

HEWSON, WILLIAM GEALE, Railway Engineering Department, Westinghouse Elec. & Mfg. Co., Pittsburg, Pa.

HICKS, LYLE JEWETT, Tester, General Electric Co.; res., 126 Elmer Ave., Schenectady, N. Y.

HIGGINS, GEORGE ELDRIDGE, Superintendent of Construction, The Home Telephone Co., Portland, Ore.

HIRSCHBERG, HERMANN M., President & Treasurer, The Excello Arc Lamp Co., 30 East 20th St., New York City.

HORGAN, JAMES GALVIN, Asst. Engineer, The Consolidated Light, Power & Ice Co., Joplin, Missouri.

HUSSEY, CHARLES E., Construction Foreman, Westinghouse, Church Kerr & Co., 10 Bridge St., New York City.

JENKS, CHESTER HORACE, Superintendent, Northwestern Tel. & Tel. Co.; res., 36 No. James St., Carthage, N.Y.

JEWETT, FRANK N., Sales Manager, Wagner Electric Mfg. Co., 6400 Plymouth Ave., St. Louis, Missouri.

JOHNS, ALBERT NEWTON, Switchman, The Home Telephone Co. of Puget Sound; res., 803 So. L. St., Tacoma, Wash.

JOHNSON, JAMES CURTIS, Chief Clerk to Supt., Telegraph, Pennsylvania Railroad Co., Broad Street Sta., Philadelphia, Pa.

JONES, JOSEPH STANSBURY, Electrician, U. S. Gov't., Norfolk Navy Yard; res., 415 S. Clay Ave., Norfolk, Va.

KELLETT, WILLIAM PLATT, Chief Engineer & Asst. Gen. Manager, The Grand Valley Ry. Co.; res., 130 Chatham St., Brantford, Ont.

KENNEDY, HERBERT HARLEY, Supt. of Traffic, Central New York Tel. & Tel. Co.; res., 321 Montgomery St., Syracuse, N. Y.

KENNEY, TIMOTHY AUGUSTUS, Asst. Manager of Operating Dept., Hudson River Electric Power Co., 82 State St., Albany, N. Y.

KIFER, EDWIN HENRY, Supt. of Distribution, Madison Gas & Electric Co., Madison, Wis.

KING, JESSE CRITZ, Superintendent, Willson Carbide Co., St. Catharines, Ontario.

KLONOWER, ARTHUR A., Engineer & Estimator, Francis Brothers & Jellett, Inc., Broad & Wallace Sts., Philadelphia, Pa.

LAMBERTON, BENJAMIN PAULDING, JR., Representative, General Electric Co., Metropolitan Bank Bldg., Washington, D. C.

LASAR, FRANK JOSEPH, Electrician, U.S.S. Vermont, United States Navy; res., 5889 Bartner Ave., St. Louis, Mo.

LIBBY, MALCOLM MARK, Engineer, The Engineering & Maintenance Co., 604 Mission St., San Francisco, Cal.

MACDONALD, THOMAS, Inspector Meter Testing Department, Westinghouse Electric & Mfg. Co.; res., 447 West 34th St., New York City.

McCarthy, John A., Electrician, General Chemical Co., Bayonne; res., 218 3rd St., Elizabeth, N. J.

Miller, Earl Wells, Postal Telegraph-Cable Co., 1326 Chestnut Street Philadelphia, Pa.

Mitchell, Lindsay LaClair, Electrical Engineer, Pittsburg Transformer Co.; res., 5108 S. Atlantic Ave., Pittsburg, Pa.

Morgan, Harold Hudson, Mechanical Engineer, Robert W. Hunt & Co., 1121 The Rookery, Chicago, Ill.

Morse, John, Engineer, The Shawinigan Water & Power Co., Bank of Ottawa Bldg., Montreal, Canada.

Peterson, Edward B., Wire Chief, Iowa Telephone Co., Keokuk, Iowa.

Plank, Ray, Switchman, Home Telephone Company of Puget Sound, Tacoma, Wash.

Pocock, Merton Albert, Electrician, The St. Paul Gas Light Co.; res., Hotel Ryan, St. Paul, Minn.

Quimby, Lewis, Electrical Engineer & Salesman, Allis-Chalmers Co., 94 First St., Portland, Ore.

Rahmberg, Hugo Magnus, Asst. Electrical Engineer, The Swedish State Railways; res., Vastmannagatan 31, Stockholm, Sweden.

Rickards, Albert Edward, Salesman, Westinghouse Electric & Mfg. Co., Pittsburg; res., 635 Park Ave., Avalon, Pa.

Ring, Samuel, Engineer, W. S. Barstow & Co., 419 Failing Bldg.; res., 46 North 21st St., Portland, Ore.

Robb, William Arthur, Chief Operator, Western Union Telephone Co., Portland, Ore.

Roberts, James Thomas, Electrician, The Biltmore Estate, Biltmore, N. C.

Schoepf, Alfred Walter, Electrician, The Washington Water Power Co.; res., 24½ East Third Ave., Spokane, Wash.

Seager, Charles Allan, Manager, Christchurch Branch, Turnbull & Jones, Ltd., Christchurch, New Zealand.

Shartle, Samuel Grant, Captain, Coast Artillery Corps, Fort Monroe, Va.

Smith, Tracy, Testing Department, General Electric Co., Schenectady, N. Y.; res., 77 Chestnut Ave., Waterbury, Conn.

Stare, Burton Reeme, 522 Pacific Block; res., 4452 Darrow Street, Seattle, Washington.

St. John, Edward, Assistant Treasurer, Westinghouse Electric & Mfg. Co., 165 Broadway, New York City.

Stuart-Menteth, William Frederick Electrical Engineer, Public Works Dept., The Bombay Government, Bombay, India.

Swallow, Joseph George W., Supt. of Installations & Inspections, The United Elec. Lt. Ht. & Pr. Co., 1170 Broadway, New York, City.

Talpey, Alfred Henry Eugene, National Electric Equipment Co., Treasurer & Con. Engineer, 21 Bromfield St., Boston, Mass.

Turlay, Chester C., Local Manager, Portland Railway, Light & Power Co., Vancouver, Washington.

Vieillard, Louis Fernardo, Draughtsman Signal Dept., The Long Island Railroad Co.; res., Woodhaven Ave., Ozone Park, L. I., N. Y.

Wagner, Frank Caspar, Professor of Steam & Electrical Engineering, Rose Polytechnic Institute; res., 1111 So. 6th St., Terre Haute, Ind.

Wakeman, Henry Relyea, Assistant to Transmission Engineer, Portland Railway, Light & Power Co.; res., 770 Northrup St., Portland, Ore.

Walker, Edward Fayers, Traveling Salesman, The Electric Appliance Co.; res., 2925 Esplanade Ave., New Orleans, La.

Wardwell, Arthur Soper, Wire Chief, The New York & New Jersey Telephone Co.; res., 495 Washington Ave., Brooklyn, N. Y.

Wenger, John Alan, Construction Department, Canadian Westinghouse Co., Hamilton, Ontario.

Wilson, James Newburk, Assistant, Electrical Dept., City of Toronto; res., 277 Jarvis St., Toronto, Ont.

Wood, Elvin Morley, Demonstrator in Electrical Engineering, University of Toronto; res., 10 Henry St., Toronto, Ont.

Young, Russell, Mechanical Electrician, Vancouver Power Co., and British Columbia Elec. Ry. Co., Lake Buntzen, B. C.

The Secretary further announced that the following Associates were transferred to the grade of Member.

Charles Frederick Lacombe, Chief Engineer, Light & Power, Dept. of Water Supply, Gas & Electricity, New York City.

Worrall E. S. Temple, Associate Professor of Electrical Engineering, Univ. of Pennsylvania, Philadelphia.

Johann Emil Leonarz, Electrical Engineer, Mexican Light & Power Company, Mexico City.

Henry Rufus King, Chief Engineer, Power Apparatus Dept., Western Electric Company, Hawthorne, Ill.

Robert Sibley, Consulting & Hydraulic Engineer, Missoula, Montana.

Mr. A. B. Reynders, general engineer, insulation works, Westinghouse Electric and Manufacturing Company, then read a paper entitled " Condenser Type of Insulation for High-Tension Terminals." Mr. Reynders was followed by Mr. K. C. Randall, electrical engineer, Westinghouse Electric and Manufacturing Company, who presented a paper entitled " High-Voltage Transformers and Protective and Controlling Apparatus for Outdoor Installation." After the reading of the papers a number of demonstrations were given of high-tension terminals by Mr. Reynders, the voltage running to 165,000, 220,000 and 225,000, respectively. At the conclusion of the demonstrations the papers were discussed by the following named gentlemen: W. S. Moody, P. H. Thomas, D. B. Rushmore, P. M. Lincoln, E. M. Hewlett, S. Piek, J. S. Peck, R. D. Mershon, G. Semenza, A. E. Kennelly, N. J. Neall, W. S. Franklin, G. Faccioli, C. L. Muralt, V. D. Moody, M. W. Franklin, Ralph W. Pope. The meeting was held under the auspices of the High-Tension Transmission Committee.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the Secretary before June 1, 1909.

8550 Farr, R. W., Jr., Ossining, N. Y.
8551 Freeman, E. H., Chicago, Ill.
8552 Jessup, A. H., Vallicita, Cal.
8553 McSoley, F. B., Providence, R. I.
8554 Nourse, W.E., So.Framingham, Ms.
8555 Preston, J. C., Cos Cob, Conn.
8556 Thomas, Henry, New York, N. Y.
8557 Evans, L. M., New York, N. Y.
8558 Finelly, W. C. J., Sacramento, Cal.
8559 Gridley, S. D., Ithaca, N. Y.
8560 McGirr, C. H., Portland, Ore.
8561 Owen, A. B., Ridgway, Pa.
8562 Peavey, J. E., Cincinnati, Ohio.
8563 Reynolds, C. W., Portland, Ore.
8564 Rockwood, J. A., Portland, Ore.
8565 Wolff, A. J., Portland, Ore.
8566 Loughridge, M.H., NewYork, N.Y.
8567 Masterson, W. D., Galveston, Tex.
8568 Secrest, C. M., Iowa City, Iowa.
8569 Adams, L. F., State College, Pa.
8570 Beetem, F. G., Philadelphia, Pa.
8571 Combs, A. F., Portland, Ore.
8572 Doying, W.A.E., Washington, D.C.
8573 Drury, G. L., Newcastle-on-Tyne.
8574 Glass, W. M., Pasadena, Cal.
8575 Harvey, A. L., Lincoln, Nebraska.
8576 Kelly, D. J., Morenci, Arizona.
8577 Lee, E. E., Culebra, C. Z., Panama.
8578 McKennon, B. C., Shreveport, La.
8579 Wallis, R. S., Ames, Iowa.
8580 Wilson, J. H., Berlin, N. H.
8581 Cryder, R. W., Guanica Centrale, P. R.
8582 Kirk, T. E., Philadelphia, Pa.
8583 Peeling, C. U., Kingston, Ontario.
8584 Phillips, D. J., Portland, Ore.
8585 Woodcock, L. R., Spokane, Wash.
8586 Jenks, H. L., Brooklyn, N. Y.

8587 Welch, L. T., Albany, N. Y.
8588 Halligan, H. A., New York, N. Y.
8589 Lincoln, H. L., Schenectady, N. Y.
8590 McNeice, Irwin, Milford, Utah.
8591 Logan, C. C., Chicago, Ill.
8592 Rogers, H. T., San Jose, Cal.
8593 Cook, C. S., Pittsburg, Pa.
8594 Poole, J. H., Washington, D. C.
8595 O'Tyson, C. E., Seattle, Wash.
8596 Wilkins, F. H., New York, N. Y.
8597 Worth, B. G., Jr., New York, N. Y.
8598 Barton, R. C., Empire, C. Z., Pan.
8599 Bentz, H. C., Minneapolis, Minn.
8600 Boettner, J., Jr., Empire, C.Z., Pan.
8601 Callahan, E. F., Schenectady, N.Y.
8602 Simmons, E., Marshall, Minn.
8603 Bammes, P. T., Garfield, Utah.
8604 Bennett, James, Montreal, Que.
8605 Breese, R. H., Atlanta, Ga.
8606 Davies, C. E., Ottawa, Ont.
8607 Elbel, A. C., Chicago, Ill.
8608 Horne, H. W., Lowell, Mass.
8609 Honn, H. V., Washington, D. C.
8610 Warren, A. H., Pensacola, Florida.
8611 Willis, R. S., Youngstown, Ohio.
8612 Ostermann, R. M., Havana, Cuba.
8613 Steele, W. R., Schenectady, N. Y.
8614 Guerra, A., East Pittsburg, Pa.
8615 Lovell, W. W., Toronto, Canada.
8616 Horey, S. S., Iowa City, Iowa.
8617 Halladay, O. W., Newton, Mass.
8618 Enderwies, G. T., Necaxa, Mex.
8619 Lacke, W. A., Chicago, Ill.
8620 Pettis, C. R., Vancouver Barracks, Wash.
8621 Howe, P. J., New York, N. Y.
8622 Rogers, J. B., Hatfield, Wis.
8623 Orcutt, D. P., Pittsburg, Pa.
8624 Edgar, G. T., Dunedin, N. Z.
8625 Kurtichanof, L., Seattle, Wash.
8626 Bunnell, C. M., Harrison, N. J.
8627 Flower, G. H., Portland, Ore.
8628 Keller, W. H., Charleston, W Va.
8629 Martin, G. R., Boston, Mass.
8630 Arakawa, Bunroku, Tokyo, Japan.
8631 Stevens, W. H., New York, N. Y.
8632 Lawrence, H. F., New York, N. Y.
8633 Henderson, S. E. M., Schenectady, N. Y.
8634 Webb, R. L., New York, N. Y.
8635 Zogbaum, Ferdinand, New York.
8636 Dunham, H. E., Brooklyn, N. Y.
8637 Sproat. D. W., Chicopee, Mass.
8638 Scott, F. W., Toronto, Ontario,
8639 Rankin, C. O., Craftonville, Cal.
8640 Edgerton, A. D., Philadelphia, Pa.
8641 Herdling, A.C.M., New York, N.Y.
8642 Hubbard, J. F., Pittsburg, Pa.
8643 Soares, J. S., Marysville, Cal.
8644 Rees, A. H., Oxnard, Cal.
8645 Crowley, W. A., Philadelphia, Pa.
8646 Hershey, Frank, Schenectady, N.Y.
8647 Palmer, G. E., Boston, Mass.
8648 Stone, Dean, New York, N. Y.
Total, 99.

Applications for Transfer

The following Associates were recommended for transfer by the Board of Examiners April 9, 1909. Any objection to these transfers should be filed at once with the Secretary.

WILSON LEE CAMPBELL, Gen. Supt., Automatic Electric Co., Chicago, Ill.

HERBERT S. EVANS, Professor of electrical engineering, University of Colorado, Boulder, Colo.

F. A. FISH, Professor of electrical engineering, Iowa State College, Ames, Ia.

H. A. HOLDREGE, Gen. Mgr., Southern Wisconsin Power Co., Madison, Wis.

THOMAS DUNCAN, Electrical Engineer and Managing Director, Duncan Electric Mfg. Co., Lafayette, Ind.

WILLITS HERBERT SAWYER, Engineer in charge, Ford, Bacon & Davis, New York City.

MILAN V. AYRES, Electrical Engineer, Boston & Worcester Railway, South Framingham, Mass.

RUDOLF EMIL HELLMUND, Electrical Engineer, W. E. & M. Co., Pittsburgh, Pa.

RUSSELL STIMSON FEICHT, Electrical Engineer, W. E. & M. Co., Pittsburgh, Pa.

R. F. SCHUCHARDT, Engineer electrical construction, Commonwealth Edison Co., Chicago, Ill.

JOSEPH F. MERRILL, Director and Professor, University of Utah, Salt Lake City, Utah.

ROBERT LEE WILSON, Electrical Engineer, W. E. & M. Co., Pittsburgh, Pa.

WILLIAM McCLELLAN, V. P., The Campion-McClellan Co., New York City.

High Tension Transmission

BY PERCY H. THOMAS

Introduction. The province of the engineer is to utilize materials and physical principles for the benefit of the community, in distinction from the statesman or the educator who have to do with men, or the philosopher, who deals with ideas. By this I do not mean that the engineer does not deal with men nor understand and appreciate great ideas, for the high class engineer must do both, but that the engineer's chief concern and ultimate purpose is the combination and control of material things for the use of the community. An electrical engineer thus deals with those engineering works that center primarily in the use of electricity.

In the planning and carrying out of a large development work, the design, construction, and operation are properly functions of the engineer. But over and beyond these, the engineer has another important function, one that is in many ways more difficult than actual design and construction; for he must furnish the information or data upon which will be based the decision as to whether a particular work is a wise one. Here is involved the necessity of predicting construction cost, operating cost, returns, and general feasibility.

Broadly speaking, there is only a certain amount of capital available in a community for new works, and, from the point of view of the public, of the various possible projects only those that will be of the greatest general utility should be undertaken. In such cases, its utility to the community is usually pretty well measured by the returns in the form of interest and dividends that a given work can earn. This measure is naturally not an ideal one, but is the only practical substitute and is in the long run quite satisfactory. It is thus important that the engineer give an accurate estimate as to the earning power of any project that may be under consideration, for otherwise it may be undertaken with the initial expectation of a certain return and the actual trial prove the undertaking a losing one. *

Assume, for example, that a large works is to be electrified. The question arises as to whether it will be better to supply the current from a steam plant or to develop it from a distant water power. If the engineer reports that the water power will result in a cheaper and entirely satisfactory source of supply, all things considered, we may assume that this method will be chosen. Suppose, too, as often happens, that the dam costs much more than was anticipated, and when the system is running it is found that the water supply is so low in the dry summer months that a steam plant has to be built after all, to carry the load at such times. It will then be seen that a considerable amount of capital has been wasted and that the water power should never have been developed for this purpose. The wasted capital would perhaps have been sufficient to build a steam plant of double the capacity. In this case the engineer is clearly at fault; he should have foreseen that the dam would have cost too much and that the water supply would prove unreliable.

Thus the responsibility of the engineer is very great, for the expenditure of the capital of the community, which is its wealth, is determined largely by his estimates of the probable costs and returns; and if these estimates are uniformly bad, the community will be to that extent impoverished. A bad engineering mistake may be as much of a real calamity as a great fire.

While the engineer usually supplies the data on which new works are determined upon, he is not usually the person who makes the actual decision as to the particular work for which capital shall be used. This decision is usually made by the financier or the representative of the capitalist; for as a matter of actual experience the best of engineers occasionally makes mistakes, and many engineers are biased. The wise capitalist, therefore, usually prefers to reserve for himself the judgment of the more general and indefinite factors which are oftentimes of more ultimate importance in the success of a project than the construction cost and operating expenses. Such general factors would be: the probable growth of population, where this element is important; the probability of legislative limitations; the competition of hostile rivals; and even the probable extent of the actual demand for the work undertaken.

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* A paper read at a meeting of the Schenectady Section, February 4, 1909.

The capitalist is usually in a difficult position, on account of the large degree of uncertainty that surrounds most projected work. If he knew, or if his engineer could tell him with certainty what the result of any undertaking would be, there would be little difficulty in deciding what work to undertake. Experience has shown, however, that it is difficult to foretell the outcome. There often occur unforeseen contingencies and items of expense; estimates of cost often fall short of actual requirements; with the result that many projects that were undertaken with the expectation of satisfactory returns have proved disappointing. While, in the nature of things, a good deal of this uncertainty is unavoidable, yet it is unfortunately true that often engineers fall far short of their duty in making too favorable a report on a project that they investigate. In doing such work it should be the clear and constant aim of every conscientious engineer to foresee as many as possible of the dangers and disadvantages of the projects on which he reports, and not to paint the prospects more brightly than the circumstances really justify.

This principle sounds well and at first seems so natural as to go without saying, but the temptation for the engineer to make his report favorable is often very strong, as when he expects to do the engineering design work for a fee if the project is undertaken, or where some of his associates have already made a favorable report, or perhaps where they have something to gain indirectly by the acceptance of the project.

This discussion of the responsibility of the engineer and his relation to the capitalist is intended as an introduction to the consideration of the phase of the subject of high-tension transmission which I shall now treat.

My plan is to discuss, of necessity briefly, the principal questions that will have to be considered by the electrical engineer in connection with a specific high-tension transmission project which may come to him. This discussion will come under three heads, the consideration of the general factors governing; first, the feasibility of the project; secondly, the earning power; and, thirdly, the actual design of an adequate plant.

Feasibility. The question of feasibility, strictly speaking, rarely arises except in very large work, since almost any plant can be constructed if the cost be not limited. There are, however, a number of conditions which virtually render some projects unfeasible. For example, in a hydraulic plant where only a very small head is available, it will sometimes happen that the variations of water-level above and below the dam will be so great that it is not practicable to get an actual setting of the turbines where there will at all times be a sufficient head for operation.

Large dams, and especially high ones, require good firm foundations, rock being preferred. Sometimes rock foundations cannot be obtained and the dam becomes impracticable, not only on account of the danger of sinking, but also on account of the difficulty of making the dam water-tight. A leaky dam not only wastes water, but is liable to become undermined.

Again, in some places relatively far north the effect of ice in winter would make the power unreliable. Some streams giving a good flow of water most of the time occasionally go practically dry. Since a system must usually undertake to supply reliable and continuous power, such a condition would make a project unfeasible.

High cost can render any project, however satisfactory otherwise, unfeasible.

There are few conditions except length that limit the feasibility of electrical transmission. These limiting conditions might be: very rough and inaccessible localities; localities subject to snow slides or land slides; and those favoring the rapid growth of tropical jungles—all these might be classed as impracticable.

Small amounts of power cannot be transmitted to long distances economically, except to mining camps and such places where a very high price can be obtained for the power. Of course, also, a particular project may be unfeasible at a particular time because money to finance it cannot be obtained or because the returns will not be sufficient.

Earning power. The determination of the earning power of a projected plant is one of the most uncertain and unsatisfactory tasks that an engineer has to undertake. In the first place, it is very difficult to foresee just how much power can be sold in a given community. If it is a residential district that is to be lighted, there is not only the question of the presence or probability of gas competition, but also the temperament and habits of the people to estimate. If the community be a manufacturing one, it must be estimated how many manufacturers can be persuaded to recognize an advantage that may actually exist for them in the use of electric power. Then again, the question remains as to the future growth of this particular community, whether it will be important or whether some discovery of new supplies elsewhere or a new railroad connection favoring some other place may not cause its decline. Once the plant is installed, it is usually too late to transfer it anywhere else to follow a removing demand, so that probable future conditions must be considered and allowed for in the estimates. Fortunately, communities change slowly and important movements are seen some distance ahead.

The phenomenon of temporary growth and prosperity followed by decline often occurs in mining communities; here great caution must be observed in estimating future earnings. Sometimes large plants are constructed at sources of cheap power with the expectation that users of power will be attracted to the neighborhood, although none is there when the project is determined upon. This is a particularly precarious undertaking, as users of power are extremely conservative. Even at Niagara Falls, it was a long time before many industries were found to utilize the offered power. During recent years, however, there has been no trouble on the part of the original Niagara Falls Power Company in disposing of its large capacity.

Again, what appears to be a good market at profitable prices may be turned into a losing one by a change in the cost of competing power, as by the discovery of oil-fuel in the vicinity, or the building of a larger, more modern, and more efficient competing plant by hostile capitalists.

On the other hand, all influences are not unfavorable; for most communities grow, and there are almost always many cases where electric power will be used regardless of other forms of power offered. And, too, new uses often arise, not initially foreseen. All of these factors tend to protect and insure the ultimate success of a plant.

Cost. The estimate of cost is usually arrived at roughly by a comparison with the cost of other similar plants, and more closely by making a careful design and estimating the cost of the individual items. The treatment of this subject is not appropriate to the plan of my talk this evening and will be omitted, so that fuller consideration can be given to the principles of design, which is, of course, one element in the determination of cost.

Underlying principles of design. It is not my object to discuss the details of structures of apparatus such as transformers and switches, but to call attention to the most important principles governing the selection of the individual pieces of apparatus that shall combine to produce a coherent and harmonious whole. It is much more important that the various elements used shall be adapted to coöperate with one another, and to the specific purpose they are to serve, than that they should be of the most efficient or the most highly developed form. I shall further limit this paper to the consideration of the high-tension portion of the system.

The line. The economy of a line is to be judged, not by its electrical efficiency primarily, but by the amount of annual charge that it makes upon the receipts of the system. When the plant is actually constructed and the capital expended, the net earning power of the investment is the total income less the total expenditures. In this statement account must be taken of all contingencies occuring over a number of years, so that any one year's statement is comparable with that of another. That is, maintenance must be regularly charged and depreciation allowed each year on all apparatus which has a limited life and will ultimately be replaced. Otherwise, a very heavy charge must be made during some one year while other years make too favorable a showing. In computing line losses, an appropriate full account must be taken of the load-factor of the plant and of all other conditions affecting the total losses. The amount deducted as annual line expense from the gross plant income is made up largely of factors that are constant, regardless of the actual amount of power transmitted by the line. These factors are, for example: the interest on the capital actually expended in the line; the percentage of this amount allowed for maintenance each year and the further percentage allowed for depreciation; and certain smaller items, such as taxes and a portion of the administration expenses, as well as the largest part of the labor of linemen, and inspectors. There are also some expenses proportional to the amount of power transmitted, which, however, do not amount to very much in a high-tension line.

It is clear as well that since there is a certain amount of power lost in the lines that by putting in more copper this loss would be reduced. The lost power if available could presumably be sold at the same price as the rest of the power, so that, broadly speaking, the most economical line will be the one which is so laid out that an increase in the amount of copper would cost more in interest, etc. than the increased power could be sold for, and at the same time that a decrease in the amount of copper would reduce the interest charges a less amount than the added power-loss would reduce the income. This is called Kelvin's law. This condition is found when the annual interest charge on the line copper is equal to the value of the lost power.

But the practical determination of this condition is a difficult matter, as the plant is not operated at a given load at all times. The maximum number of kilowatts is lost at the time of maximum load, and as the load goes down, the loss is less in absolute value. Thus the total amount of actual power that is lost will be determined by the average loss; not by the maximum loss. Again, if the loss be reduced and the power saved be sold, it will be necessary to have larger apparatus at the receiving station, which will increase the cost and investment charges somewhat. Furthermore, the full amount of the saved power cannot be sold for the full 24 hours. The interest charges on the copper investment are, of course, independent of the actual load on the line. As a result of these conditions it will usually be wise to interpret Kelvin's law conservatively; that is, to make the investment in copper as small as possible without clearly involving a loss of power which could in all probability be sold profitably. In such a case it is important to consider the possibility of a future increase in the plant capacity. By these considerations the expenditure in copper required for a given case may be determined.

The next question, considering the electrical characteristics, is the regulation of the line; that is, the voltage variation at the receiving end with different load conditions. A system in which the load-voltage varies greatly from time to time is unsatisfactory for most purposes, and in commercial service is not generally acceptable. Thus it is necessary that the voltage-drop in the line be not very great. But this drop is not the only loss of voltage between the generator and the load; the step-up transformers and the step-down transformers, as well as the secondary apparatus and distributing lines, all add to the total. There will be naturally from 5 to 10 per cent drop at full load in the various parts exclusive of the transmission line, so that there will be naturally a very considerable total drop in any actual system.

For the types of load sensitive to voltage changes there is often used some sort of feeder regulator which alters the voltage of a particular circuit to keep it constant regardless of the line voltage. These regulators are somewhat costly, cause additional losses, and introduce an element of uncertainty into the operation of the system, and are thus undesirable. The greater the range of voltage to be corrected, the larger the capacity that must be provided in the regulating apparatus. All things considered, then, the variation of voltage should be made as small as is practicable, and as the line-drop is the largest item in this drop it must be kept small. The actual most suitable values must vary with different cases, but usually the line-drop should be kept below 10 per cent. In long lines it is difficult to keep down this drop and larger values may be used. Where important receiving apparatus is connected at or near both ends of the line, the voltage variations are more difficult to control and the drop should be less than usual.

The calculation of inductive drop is an interesting problem, and usually it is not very difficult. In lines where the capacity current is not high, that is, in short lines with relatively heavy load, the problem is similar to that of calculating the drop of voltage produced by any current flowing in a conductor having resistance and reactance. In other cases where the capacity current is considerable the results given by this method are not sufficiently accurate; for there flows through the line and in the generator not only the load current, which will usually be lagging, but there also flows at the same time the line charging current. This current has a value of zero at the receiving end of the line, but it becomes gradually greater toward the generator and until there it is equal to the total capacity current of the whole line. Thus it is clear that there is in such a line no single value of current by which to calculate the drop. However, a sufficiently accurate determination of the drop can be obtained for all but the longest lines by assuming one half of the line capacity connected as a condenser across the line at the generator and the other half at the other end: With this assumption the current in the line is the same at all points, and the drop calculation can easily be made. This is not the only method of approximation, but it is a good one. If preferred, the total capacity of the line can be considered to be concentrated at the center. The numerical results will be about the same in the two cases.

In making these calculations, it is important to remember that the charging current is not in phase with the load current, and these currents must be combined in the usual manner for currents not in phase.

Since the line-charging currents tend to balance the lagging component of the load current, it is helpful in raising the power-factor at the generator and thus reducing its losses and its cost.

So far the calculation has been assumed to be for a single-phase circuit, while all commercial circuits are three-phase circuits. A convenient rule for calculating the drop in three-phase lines is as follows: the percentage line-drop and percentage energy line-loss of a three-phase transmission circuit will be the same as the same percentage quantities calculated for a single-phase line transmitting one-half of the amount of power over two wires of the same size and with the same spacing as any pair of the three-phase wires. This assumes the three line wires to be arranged approximately at the apexes of an equilateral triangle.

The matters of copper loss and regulation are very closely linked to the voltage of transmission. The transmission voltage should be taken as the highest that can be used without too greatly increasing the cost of the step-up transformers, the high-tension switches, and the line construction. The additional cost of buildings and line outlets due to very high tension also become an important item with short distances. It is of course true that the line-losses and the line-drop are reduced in proportion to the square of the line voltage so the advantage of the high voltage is great. If the voltage be raised so high that the cost of copper becomes much less than the cost of the rest of the line, the extra cost of the insulators, poles, etc., due to increased voltage, will much more than balance the saving in copper. Furthermore, it is sometimes possible to use so high a voltage that the economical size of copper will be too small to be safely used.

As a matter of fact, lines are usually designed by working out the loss, the line-drop, the cost of copper, and the cost of other parts of the transmission line for a given set of assumptions as to voltage and size of wire and then finding the effect of varying one or the other element tried to see if a better condition can be found. An experienced engineer can reach conclusions very quickly while a less experienced man might reach the same result only after many trials.

The size of wires actually used range from No. 4 or No. 5 up to No. 0000, and the pressures up to 50,000 or 60,000 volts for distances from 50 miles up and as much higher voltages for longer distances as the engineer dares to use. At the present time, 100,000 volts is about as high a pressure as can be safely undertaken.

There remains of the electrical features of the system the determination of frequency. All power transmission in this country, leaving out of account the use of 15 cycles for railway work, will be at either 60 or 25 cycles. The great majority of plants now in operation are at 60 cycles. For small and moderate size plants giving miscellaneous service this is without doubt the better frequency of the two. The advantage of this frequency is that it is wholly satisfactory for arc and incandescent lamps, while 25 cycles is not at all adapted to arc lamps and not generally satisfactory for incandescent lamps. The arc-light load can, however, be carried satisfactorily from mercury rectifiers, at least as far as outdoor lighting is concerned, but no general solution of the difficulty with incandescent lamps is so far available. On the other hand, in making large motors it is of great advantage to have 25 cycles. For transformers, 60 cycles is to be preferred. The transmission line-drop will be much greater on long distances with 60 cycles than with 25; this fact will be almost a determining factor in long transmission. Again, many plants have to transmit power to actually existing 60-cycle plants, and must either thus transmit at 60 cycles or transform for these installations. This condition may determine the choice of frequency. It will usually be clear in any given case which frequency is the best one for a particular plant.

With the frequency, size of copper, and voltage chosen, the electrical features of the line are practically determined. The problem then becomes one of a more or less mechanical nature; that is, the insulating and supporting of these conductors under the actual conditions in which they must serve.

This problem is double. First, there is the insulation of the line wires; secondly, their mechanical support against the strain of the wind and the weight of snow and ice. The latter aspect will be considered first. The controlling factors here are cost and reliability.

The oldest pole lines followed the telegraph practice, and used wooden poles and wooden cross-arms supporting the wires from insulators on wooden pins. This method had and still has the advantage of relatively low first cost, flexibility, convenient accessibility of materials (this last consideration has now largely disappeared in most localities in the United States) and extreme readiness of construction. The wooden pole line has, however, the disadvantages of unsatisfactory mechanical reliability and rapid deterioration. As usually installed, the poles rot quickly, are easily broken by unusual strains, are readily burned off, and are not at all uniform in their mechanical characteristics. Furthermore, there was much trouble in the early days—in fact until the present time—with the burning of poles and cross-arms and pins by current leaking over the insulators or passing through broken insulators. These things rendered it very difficult to maintain continuous service and engineers tried to find some means to improve the mechanical reliability of the line.

The natural method was the substitution of steel poles or towers for the wooden poles; at the same time the cross-arms and insulators were made of metal to prevent the burning that had been found so troublesome with the wooden parts. This was a radical change in construction but was quickly accepted by engineers. The result of the use of steel construction is a gain in mechanical features but an increase in the danger of shutdown of the plant from lightning and such disturbances and from broken insulators. With the old wooden structures, when an insulator was broken or lightning jumped around it there remained the insulation of the wood to protect the line; the wood burned off often, but not always, and the line frequently was not shut down. Nor was the generator completely short-circuited by such an accident. On the other hand, with pins dead grounded through the supporting structure, every failure at the insulator is a low-resistance short-circuit on the line, and all the harmful results that follow such a short-circuit happen each time that a disturbance occurs on the system. Again, those lightning or other static disturbances which are not of maximum severity do not as often cause a break at the insulator when it is mounted on a wooden pin and a wooden-cross arm.

Thus there are advantages and disadvantages with either steel or wooden pole lines. Usually steel poles are preferred for large important lines, while wood is still often used in less important plants or in localities where it is plenty and deterioration not rapid. In most parts of this country at the present time it is difficult to obtain good wooden poles in large quantities at a reasonable price.

Poles are occasionally constructed of reinforced concrete, but while they are permanent, strong, and flexible, they are expensive.

It is sometimes possible to lessen the severity of short-circuits due to grounds on metal-pole lines by grounding the middle point of the high-tension circuit through a resistance. For then, when only one ground at a time occurs on the system, the current following this ground must pass through the resistance and thus be limited in its severity.

Line insulators are chosen to give an especially large margin of safety with the metal structures.

The fact that metal or steel poles cost many times as much as wooden poles means that fewer must be used, or the line costs would be prohibitive. Fortunately, steel poles, or towers as they have turned out to be, can readily be made very much stronger than wooden poles, and the use of long spans between towers reduces the number necessary.

The limit of the length of span that can be used with steel towers is determined largely by the mechanical strength of the conductors, which will rupture if the span is too long. The heaviest strain on a wire is caused by an accumulation of ice. This is an unfortunate condition, for the occurrence of such thick ice or snow layers is a rare occurrence at any one point, so that the expense of the line may be greatly increased to provide for this exceptional condition when it will probably never occur. In calculating actual line structures it is customary, however, to assume a considerable thickness of ice on conductors. This ice layer may weigh much more than the wire itself.

But the ice situation is still further complicated by the presence of wind. A considerable strain is added on the suspended conductor by the wind which tends to deflect it. When wind and ice come together the strain is, of course, much increased. This condition may easily occur, though as a matter of actual fact it is seldom seen. There is a great deal of variation in the margin of safety used by engineers in this matter of ice and wind, since there is no way but pure assumption of arriving at what the maximum condition will be in any given case.

Some engineers take 0.5 in. of ice on the conductors all the way round as the worst condition, while actual instances of ice more than twice as thick have been observed. There is also a considerable variation in the maximum wind velocity, values from 40 to 75 miles an hour being used. As the wind pressure varies as the square of the velocity, roughly, this variation of velocity means a much greater variation in actual pressure. A velocity of 70 miles an hour corresponds to about 20 pounds pressure per square foot on a flat surface. It has been found by experiment that the pressure on a cylindrical surface is only from one-half to five-eighths as much as on a flat surface.

But the conductor is not the only part of the structure that must support those strains. The towers must stand the dead weight of the conductor with its weight of ice and the wind strain. They must withstand this strain in any direction that it can be applied. It must further support the strain due to the breaking or the melting off of one or more of the conductors at any point. Such an accident brings a severe strain on the tower, tending to twist it when only one or two wires of three are broken or to pull it down in the direction of the line when all are broken.

It is relatively easy to get the necessary mechanical strength in the steel structures, but often in details the design or construction may be found inadequate. For example, the strains just spoken of are applied at three or six points on the structure according as it carries a single or a double line, and there may not be sufficient strength to bear the strains locally at these points. Furthermore, twisting strains are not easily provided for in some types of tower structures.

In addition to the matter of the strength of towers, there follows the necessity of so firmly setting them in the ground that they will not be upset by the various strains to which they are subjected. With the old wooden poles the spans were much less, and a pole well set in firm earth was stable enough to stand any load without coming out of the ground. But with towers which have many times as much strain to support, no such hold on the earth will serve to keep them in position. Either foundations must be put several feet down in the earth or heavy foundations used, holding by dead weight, or the structures must be guyed to prevent overturning.

Insulators must of course be strong enough to support the mechanical strains but as each line wire has its own insulator it is feasible to get sufficient strength here even though porcelain is not mechanically well adapted for this purpose.

There are many special problems and difficult details of line construction that might be discussed, but the main considerations of the mechanical structure of the line have been considered.

The forcing of current to remain on the line is one of the very troublesome high-tension problems. The insulator must first of all hold normal potential and all the unusual voltage variations, static or other sort, up and down. So much is not particularly difficult to secure and does not usually mean more than two or possibly two and one-half times normal potential. But there remains the question of lightning with several times normal potential applied locally to the line with the generator voltage ready to follow any break to ground. This danger and the danger of mechanical failure in the line are the two most important threats of interference of operation. The danger of lightning may to advantage be a little more fully discussed.

Lightning affects not only the line itself but also the apparatus connected to the line, such as the step-up and step-down transformers. The latter are protected by some one or more of a number of commercial types of arrester which are suitable to discharge static disturbances freely to ground and at the same time to suppress the flow of current from the generator. This apparatus is now fairly well understood.

The effect of a lightning disturbance on the line proper is somewhat different from that on the terminal apparatus. For the purpose of illustration the line may be considered a long narrow trough with high sides partly filled with water. A lightning stroke may then be taken as the dropping of a large quantity of water upon the trough at some particular point, which then overflows at this point, the surplus being spilled over on the earth. In view of the fact, however, that the trough has high sides a certain portion of the water will be retained, and this portion will spread in both directions and send two waves along the line. If these waves find any weak spots in the trough they will cause a spillover. Similarly with the direct lightning stroke.

The water or the electric waves passing along will finally come to the end of the trough, where they will be reflected and sent backwards into the line. At this point of reflection the height of the wave will be doubled momentarily, thus tending to cause a spillover at this point. The reflected wave will gradually dissipate itself and the excess water be distributed along the trough. When the line or trough divides into two parts, the wave will likewise divide into two waves which will have but half the height of the original; that is, a divided line tends to reduce the severity of the wave.

Thus every lightning stroke reaching a line wire will cause a violent discharge to ground at this point and will likewise send waves of " static current " through the line in both directions, which will traverse and spread over the whole system, being reflected at the ends of lines with the production of double the potential of the wave at the moment and at the point of reflection and gradually becoming dissipated and uniformly distributed over the system. It is these waves when actually reaching the ends of the lines and the terminal apparatus that are discharged by the station lightning-arresters.

But a line may be affected by electromagnetic or electrostatic induction from a lightning discharge which does not actually reach the line. This effect is similar to the effect on the trough of water produced by a gradual raising or lowering followed by a sudden lowering or raising the level of the trough at some point. This may cause a spillover and will cause the production of traveling waves as in the other case.

It is clear that the absolute protection of a transmission line from lightning is difficult. The best available method at the present time is the use of overhead ground wires, which, if properly grounded at very frequent intervals and well spaced from the transmission wires, will shield the line from direct stroke and to some extent from inductive action. Similarly, a roof over the trough of water would protect it from a discharge that would otherwise cause a spillover.

Conclusion. I have now briefly touched on the several conditions and features of a high-tension transmission line which are the most important to the engineer in studying any given system or project. It can be seen that these are almost entirely independent of the actual details of design of the individual parts of the apparatus. Such design matters are usually beyond the scope of the transmission engineer; they are properly within the province of the manufacturer. It has further been shown that the commercial or financial features of a transmission system or project must not only be considered by the engineer, but that these are perhaps the most important considerations of all.

I wish to call attention to but one other feature of practical work, applying in a much wider field than high tension. To avoid the large numbers of unnecessary and excessively annoying small mishaps, failures, discrepancies, and inadequate details that are almost impossible wholly to avoid, the designing engineer, who should have had a large experience and also a naturally favorable instinct or temperament or imagination or whatever it may be called, should carefully review all the details in his design of the plant for the purpose of eliminating such minor difficulties.

Pacific Coast Trip

The ninety-seventh meeting of the American Institute of Mining Engineers is to be held next autumn, and will embrace sessions at Spokane, Seattle, Salt Lake City, and a trip through Yellowstone Park. The particular time selected for the meeting has been dictated by several considerations. The celebration of the one hundred and fortieth anniversary of the discovery of San Francisco Bay begins October 19. The annual meeting of the American Mining Congress will begin at Goldfield, Nevada, October 25. The Alaska-Pacific-Yukon Exposition, which is to be held at Seattle, closes October 16. As the Yellowstone National Park is closed to visitors September 25, the date for the start of the Institute party has been set for September 23. It is not intended to include San Francisco and Goldfield in the regular schedule, nor Butte and Anaconda where brief stops may be made, but the excursion has been arranged so as to enable such members as can spare the time to make supplementary visits to these localities. The stay at Salt Lake City will permit the inspection of important mines and works in Utah. The excursion will start from Chicago September 23, returning to that city in about 30 days. The expense of the trip from Chicago to Chicago, for transportation, berth and meals on the train, stage hire, hotel accommodations and meals at Yellowstone Park, will be $300.00 for each passenger. Those preferring to go to hotels at Spokane, Seattle, Salt Lake City, or elsewhere, can receive no rebate on that account. The accommodations on the train, already paid for, will be at their disposal. This arrangement is contingent upon at least 100 members and guests taking part. Any A.I.E.E. members desiring to join the party should communicate with Mr. Theodore Dwight, 29 West 39th Street, New York City.

Sections and Branches

ARMOUR INSTITUTE OF TECHNOLOGY BRANCH

The Institute paper on the " Log of the New Haven Electrification " formed the subject of discussion at the meeting of the Branch held on March 5. Mr. Perrin discussed the relative cost of alternating-current and direct-current railway construction, and gave some figures bearing on the subject. Mr. Rosenthal brought out the advantages of the catenary construction for high speed heavy electric traction. Mr. Van Etten showed the disadvantages of the single-phase motor, especially in difficulties of operation. Mr. Rose made a comparison between alternating-current and direct-current locomotives, showing the good points, and the serious defects of each. Mr. Simpson reviewed the history of the New York Central and the New York, New Haven & Hartford electrification, giving an instructive account of the difficulties encountered and the methods of surmounting them. Mr. Stadeker took up the subject of the auxiliary trolley wire as employed in this system, and showed some results not only on the line under consideration, but also its possibilities with other systems with similar characteristics. Mr. Downton closed the discussion with a very excellent talk on circuit-breaker troubles and impedances on the generator circuit.

The second March meeting was held in the physics hall on March 19. About fifty members and visitors were present. A paper on " Industrial Engineering " was given by Mr. Lindeburg and Mr. George M. Brill, consulting engineer. The paper dealt with the problems connected with the engineering side of the design of buildings for large industrial enterprises, such as the proper type of construction for the work to be accomplished, study of conditions governing location, class of power available, etc., all of which were discussed. Mr. Lindeburg showed the great importance of proper lighting, heating, fire protection, and ventilation, and explained how each of these could be accomplished. He emphasized the necessity of making the plans and specifications so complete that there could be no dispute, and hence practically no additional cost either to the owner in the way of extras in carrying them out, or loss to the contractors due to insufficient data for making bids. The discussion led to the conclusion that this thoroughness is unfortunately far from being a universal virtue among consulting engineers. In conclusion Mr. Lindeburg showed a number of lantern slides illustrating the subjects covered by the paper.

BALTIMORE SECTION

The Baltimore Section held its regular monthly meeting on March 19, with Dr. J. B. Whitehead presiding. There was a total attendance of 43. Professor R. W. Wood, who was to have addressed the meeting on the subject of " Some Unusual Effects of Electricity and Magnetism ", was prevented from being present by illness. The notice was too short to permit securing another paper, and in lieu of an original paper, the Institute papers read at the New York April meeting were reviewed by Dr. Whitehead and Dr. Potts.

At the meeting held April 9 Mr. H. S. Putnam, of New York, presented a paper on " Conservation of Natural Resources—An Engineering Problem." Mr. Putnam pointed out that while the waste of forests, washing of arable lands, and filling of waterways could all be more or less prevented by proper engineering methods, the waste of fuel is irreparable. Hence the necessity of preserving and using water powers. He gave much interesting data as to the amount of available power in relation to present and future demands.

Lantern slides added much to the value of the paper. Thirty-five members were present.

BOSTON SECTION

The regular monthly meeting of the Boston Section was held Wednesday, March 17, in the auditorium of the Edison Building. Dr. A. E. Kennelly, chairman, presided. Dr. Charles P. Steinmetz, of Schenectady, presented his Institute paper, recently read before a New York meeting, on "Prime Movers." A discussion took place at the close of the address, in which Dr. Kennelly, Professor Adams, and Professor Thomson participated. About 325 were present.

CHICAGO SECTION

A joint meeting of the Chicago Section and the Electrical Section of the Western Society of Engineers was held on the evening of March 2, in the rooms of the Western Society of Engineers, with Mr. W. L. Abbott presiding. About 150 engineers were present. The subject of the evening was "The Relation of Load-Factor to Power-Factor." Three very instructive papers were presented; one by Mr. E. W. Lloyd, of the Commonwealth Edison Company, one by Mr. J. M. S. Waring, of the Electric Storage Battery Company, and the third by Mr. C. A. S. Howlett, of the Western Electric Company. Mr. Howlett was ill and unable to be present, but his paper was read by Mr. Grant, of his company.

Another joint meeting was held by the Section in conjunction with the Electrical Section of the Western Society of Engineers on Friday evening, March 19. Professor E. E. F. Creighton, of Schenectady, N. Y., gave a "Demonstration of Lightning Phenomena." Being one of the leading experts in this country on the subject, Professor Creighton gave a talk of unusual interest, illustrating various phenomena of lightning and high-voltage discharges by apparatus. About 150 were present at the meeting.

CLEVELAND SECTION

The Cleveland Section held its regular meeting on March 15, with Mr. C. W. Ricker presiding, and an attendance of 65. The business of the evening consisted in acting on an announcement from the A.S.M.E. that they would in the future extend to the members of the Section invitations to their meetings when the subject was of an electrical nature. It was moved that the matter be referred to the Executive Committee to return a similar invitation. After the business had been disposed of, a paper was presented by Mr. Cady, on "Electric Heating." It dealt with the history and general application of heating appliances, as well as the theory, design, and industrial and domestic applications. Mr. Kellsey, in discussing the subject, spoke from the standpoint of a canvasser and developer, and gave an encouraging report on the attitude of the public towards electric cooking and heating, stating that there had been over 100 per cent increase in the installation in Cleveland in the last two years. Messrs. Pomeroy, Lincoln, Wallau and others, also took part in the discussion, from the consumers' and central station standpoint. The meeting was the most successful held this season.

FORT WAYNE SECTION

On Thursday, April 8, the regular meeting of the Fort Wayne Section was held in the new Hotel Anthony. The meeting was preceded by an informal dinner. Owing to the lateness of the hour the business portion of the meeting was dispensed with, and the chairman, Mr. E. A. Wagner, then presented the speaker, Mr. M. J. Kehoe, of the Fort Wayne-Wabash Valley Traction Company, who read a paper entitled "Data on Power Plant Operation." Mr. Kehoe described the different types used in some of the modern power stations and the elements in the design involved in obtaining the greatest economy of operation with these different types. The subject of double-deck power stations was also taken up, and the advantages obtained in this way in regard to simplicity of piping and other mechanical features were described. Mr. Kehoe expressed it as his opinion that turbines in double-deck stations should not be mounted on structural steel, but should be provided with some sort of concrete or brick foundation which could be obtained by building the boiler walls a little heavier and running them up to the floor under the turbine. The paper was followed by a discussion by some of the members present, who gave especial attention to the cost of power production, and also to the construction of transmission lines which would stand a heavy sleet and wind storm such as we have experienced this last winter. Mr. Kehoe spoke of his experience with his company's 33,000-volt transmission line from Fort Wayne to Lafayette in which they use a 6-ft. triangle and 200-ft. spans, and stated that this winter's experience had convinced him that such construction would stand the heaviest storms.

ITHACA SECTION

A joint meeting of the Ithaca Section and the Cornell Branch of the A.S.M.E. was held Tuesday, March 30, about 50 members of each organization being present. The meeting was presided over by Mr. H. See. The Institute paper by Mr. B. R. Shover, on "The Application of Electric Motors to Steel Mills" was abstracted by Messrs. G. D. Gates and F. L. Lucker. Mr. Gates presented the mechanical engineering features of the installation, emphasizing especially the gas engine equipment and the processes in use to fit the producer gas for driving the engines. Mr. Lucker took up the growth of motor applications in steel mill work and cited the various examples described in the paper. In the discussion that followed, Professor R. C. Carpenter compared the cost of installation and operation of gas engines and steam turbines, giving as his opinion that the latter installation would result in a lower cost per kilowatt year. This was explained in part as due to the high rate of depreciation which obtains in gas engines, due to the dust in producer gas and to the higher cost of repairs. Professor Norris showed how much more severe is the service of steel mill motors than that of the street car motor since the steel mill motor in many cases works in close proximity to white hot or molten metal. He emphasized the fact that the most important characteristics of these motors is reliability. Mr. B. C. Dennison called attention to the direct-current motors and equalizer set used in the Illinois steel plant at South Chicago. Professor Kimball referred to the too great complexity of much of the steel mill apparatus, especially the ore unloaders and automatic motor starters. Professor Hess discussed the need of an occasional shut-down of blast furnaces in order that needed repairs might be made.

KANSAS STATE AGRICULTURAL COLLEGE BRANCH

The April meeting of this Branch was held in the telephone laboratory on April 6. Mr. D. F. Foote gave a review and discussion of the Institute paper on "Condenser Type of Insulation for High-Tension Terminals." Mr. E. C. Reed reviewed the paper on "High-Voltage Transformers and Protective and Controlling Apparatus for Outdoor Installations", by K. C. Randall. A demonstration and talk on the testing of high-voltage insulation was given by Professor B. F. Eyer.

UNIVERSITY OF KANSAS BRANCH

A meeting of this Branch was held on March 17, with Mr. Ray Jones presiding, and an attendance of 18. Mr. A. J. Houghton read a lecture on "The Commercial Insulation of Wire." The lecture was illustrated by lantern slides, and was followed by a general discussion.

Another meeting was held on March 31, with an attendance of 19. Mr. Fred Bolocca presented a paper on "Alternating Current versus Direct Current for Railway Operation." Mr. W. E. Edmonds presented a paper on "The Single-Phase Railway Motor."

LEHIGH UNIVERSITY BRANCH

The regular March meeting of the Lehigh University Branch was held on March 16, 1909, at President Drinker's residence. It was well attended, about 75 being present. The first paper, by Mr. S. R. Schealer, was on "Present Status of the Tungsten Lamp." In a clear concise argument augmented by a few figures Mr. Schealer showed the economy of this new filament to all parties present concerned in its use. The second paper was presented by Professor S. S. Seifert, on the "Single-Phase Series Motor", which proved interesting from the fact that Professor Seifert is the inventor of the balanced choke-coil idea for reducing sparking on this type of motor, and because he, in conjunction with Professor W. S. Franklin, is now working on an entirely new type of railway single-phase series motor. The paper was made simple enough to be understood by everyone present, and was followed by a discussion led by Professor William Esty. The final paper was by Mr. A. S. Garrison, on "Electrolysis", in which many interesting and instructive facts were brought out. President Drinker then extended an invitation to the society to refreshments, and a pleasant social hour followed.

MADISON SECTION

The March meeting of the Madison Section was held in the auditorium of the Madison City Library building on Thursday, March 25. The paper of the evening was given by Professor Daniel W. Mead of the University of Wisconsin. Professor Mead's subject was "Hydroelectric Design and Construction in Wisconsin." His talk was fully illustrated with lantern slides and dealt with the Peshtago plant at High Falls on the Peshtago River, and the Kilbourn plant on the Wisconsin River. Hydrographs were shown to illustrate the method of determining the power available at a given fall, and following this was a discussion of methods used in determining the proper selection of wheels suited to the conditions. Some details of construction of the two plants were given. There was an attendance of 46.

UNIVERSITY OF MICHIGAN BRANCH

At the meeting of the Branch on March 31, Mr. H. B. Calkins gave a talk on "Homopolar Generators", and explained points in the machine designed by him. By the aid of his drawings he made clear the more difficult features of homopolar design. Mr. A. G. Hall, by blackboard illustrations, explained differences in the various boosters commonly used.

The meeting of the Branch held on March 17 was preceded by a dinner at the Michigan Union Club House. Short talks were given by Professors G. W. Patterson and C. L. de Muralt, and Messrs. H. H. Higbie and R. D. Parker, all dealing with plans for the work of the Branch and for the increase of membership among under-classmen. These plans are for the purpose of avoiding the decrease in membership by graduation each year. A resolution was passed that the Branch petition the faculty for rooms in the new addition to the engineering building.

MINNESOTA SECTION

The monthly meeting of the Minnesota Section was held on March 29, in the offices of the Twin City Rapid Transit Company, Minneapolis. The Institute papers on "Condenser Type of Insulation for High-Tension Terminals", and "High-Voltage Transformers and Protective and Controlling Apparatus for Outdoor Installation", were abstracted and discussed. It was the general opinion that the outdoor installation of high-tension apparatus would not be satisfactory or reliable for the northern climates where heavy snowfall and extreme cold were liable to occur. The attendance numbered 19.

UNIVERSITY OF MISSOURI BRANCH

The University of Missouri Branch held a meeting on March 25, Professor H. B. Shaw presiding, with a total attendance of 28. The Institute papers on " Prime Movers " and " Industrial Application of the Electric Motor " were presented by the chairman. In the discussion of " Prime Movers " Professors Hibbard and Westcott laid emphasis on " reliability insurance " as frequently a decisive factor in the choice of prime movers. This feature of reliability was touched on incidentally in considering the status of the electric locomotive. In taking up the next paper, " Industrial Application of the Electric Motor ", Professor Shaw spoke briefly of the flexibility and economy of the electric drive, and outlined the main workings of the Gary plant. The system of wiring and transmission used was commented upon by Professor Flowers, and the comparative merits of underground and overhead transmission were considered. Messrs. Harris, Schmander and others took part in the general discussion of the papers.

MONTANA AGRICULTURAL COLLEGE BRANCH

A meeting of this Branch was held on March 17, at which 22 members were present. Chairman Hind announced that the next meeting would be held on the last Friday of March instead of the first Friday of April, in order that Mr. Siegfried, of the Missouri River Power Company, could address the meeting. The program consisted of a lecture by Mr. Hind on his experiments on break-down tests of insulators, and was illustrated by the reflectorscope. The voltmeter for these tests was calibrated by spark-gap; the insulators were tested dry and with spray, also with outdoor conditions of wet and dry snow.

At the meeting held March 29 Mr. J. G. Siegfried, superintendent of power plants of the Missouri River Power Company, Helena, Montana, delivered an address on " Protective Apparatus for Electric Circuits." He took up the various forms of protective apparatus for excessive currents, describing in detail the different forms of fuses and circuit-breakers, illustrating each form by diagrams and photographs with the reflectorscope. He also described high-voltage protective circuit-breakers, time-limit breakers, relays, oil-switches, and the instruments and apparatus made use of in the remote control systems of the larger power plants.

NEW HAMPSHIRE COLLEGE BRANCH

The regular meeting of the Branch was held in Conant Hall March 22, 1909, at 7:30 p.m., with Professor A. M. Buck in the chair. The subject for the evening was " Machine Tool Drive ", and it was very creditably covered by Mr. Campbell, who took the electrical side, and Professor Cardullo, who took the mechanical side. Both speakers emphasized their points by means of pictures thrown on the screen. The first paper described the different kinds of motors on the market for this kind of work, and the different starting and controlling devices used. The second paper described how the first machine-tool drive was operated, and then took up the different stages of development up to the present time. It was stated that one of the hardest propositions an electrical engineer ever had was when the mechanical engineer came to him and wanted a variable speed motor built suitable for running machine-tools, especially planers and rolling mills, but this has been accomplished.

The direct-current motor has been used for this purpose almost universally up to the present time, but now the alternating-current motor is slowly coming into general use.

The April meeting was held on the 12th instant. Mr. E. R. Fellows gave a talk on "Outside Construction in Telephone Work", before a large audience. Among the features discussed were, the treatment of poles to increase their durability, the splicing of wires, arrangements to avoid interference from near-by pole lines, the guying of poles, and the proper methods of making connections to buildings in local distribution. One of the special topics was the various forms of cables for overhead and underground work, the methods of splicing them, putting them in position, and different forms of deterioration of the lead sheath, and their remedy. The lecture was illustrated by lantern slides and was discussed at some length by those present. Professor Hewitt cited an instance in his experience where a bad case of trouble from electrolysis was dealt with. The underground cable paralleled an electric railway and the lead sheathing carried some of the leakage return current from the rails. This made trouble where the cable passed from the power house, as the current in leaving the cable rapidly destroyed the cable by electrolysis. The remedy was to make a good copper connection between the cable and the negative busbar in the power house.

NORFOLK SECTION

The March meeting of the Norfolk Section was held in the rooms of the Board of Trade on March 25. The subject of the meeting was "Features of Modern Power Plant Design", by Mr. D. G. Stanbrough. Blue prints were distributed by the speaker showing the relation to each other of the various subjects under discussion. The meeting was well attended, 23 members and visitors being present, and much interest was shown in the discussion which followed the presentation of the paper.

PHILADELPHIA SECTION

The Philadelphia Section held its regular monthly meeting on April 12. The meeting was preceded by a dinner at Boothby's restaurant. It being Easter Monday, only 20 sat at the table, a smaller attendance than usual. At the meeting held after the dinner, in the auditorium of the Philadelphia Electric Company's Building, 60 were present. The paper for the evening was on hydraulics, and was to have been presented by Mr. Wm. F. White. Unfortunately Mr. White was unable to attend, and the papers committee succeeded in securing on very short notice Mr. Frank B. Gilbreth, of New York, who presented a paper on the "Effects of Earthquake and Fire on Different Forms of Building Construction as Illustrated by the San Francisco Disaster." The paper was illustrated by a series of very interesting photographs which were thrown on the screen, and showed very plainly the weak points of the different methods of construction when subjected to the severe tests that accompanied the San Francisco disaster. In the discussion that followed, a number of questions were satisfactorily answered by Mr. Gilbreth. One interesting point he brought out was that in spite of careful examination, both by himself and others connected with him, no case was found where any effects from electrolysis could be detected on steel work protected by concrete. This is equally true of the rod used in reinforced concrete and of the structural steel on which concrete had been placed as a fireproofing.

PITTSBURGH SECTION

The regular monthly meeting of the Pittsburgh Section was held in the Carnegie Institute March 9, 1909, Mr. W. E. Reed, chairman, presiding. The usual preliminary dinner was held at the University Club, 25 members attending. At the meeting after the dinner, 292 were in attendance. The subject for discussion was " Single-Phase Railways." The papers were limited to ten minutes in length, a lantern being provided to assist in the presentation of the subject under discussion. The papers presented were: " The Single-Phase Railway System ", by Clarence Renshaw; " The Single-Phase Motor ", by S. M. Kintner; Catenary Line Construction ", by T. Varney; " A Comparison Between Single-Phase and 1200-volt Direct-Current Systems ", by F. E. Wynne; " The Single-Phase System in Operation ", by G. D. Nicoll; " The 1200-volt Direct-Current System in Operation ", by Harry Etheridge. Unusual interest was shown in the discussion, which was opened by Mr. N. W. Storer, who was followed by Mr. James Bryan, one of the chief advocates of the 1200-volt direct-current system. Mr. Bryan's discussion was in a very humorous vein, and the good-natured banter between the advocates of the various systems kept up a lively interest among those present, and afforded considerable amusement. The other speakers were Messrs. W. W. Waters, B. A. Behrend, and J. S. Jenks.

PITTSFIELD SECTION

Mr. D. B. Rushmore, of the General Electric Company, Schenectady, was the guest of the Pittsfield Section at its meeting of April 1. Mr. Rushmore gave a lecture on " Use of Electricity in Steel Mills." He called attention to the tremendous growth of the steel industry, which he indicated by charts and curves thrown on the screen, showing the annual production of iron and the resulting products for a long term of years. The figures brought out clearly the well established fact that the output of pig iron is a fair index of the country's financial condition. An interesting description, illustrated by many lantern slides, was given of the immense plants of the United States Steel Corporation at Gary, Indiana. An informal dinner was given for Mr. Rushmore just before the lecture.

PURDUE UNIVERSITY BRANCH

A meeting of this Branch was held on March 16. Messrs. Howland and Meyers gave a discussion on the Gary steel plant, dealing particularly with the application of the electric motor to the steel manufacturers' process. Mr. Howland opened the meeting with a general description of the Indiana Steel Company's works, together with a brief outline of their method of electrical distribution. Following Mr. Howland, Mr. F. D. Myers took up the specific application of motors, particularly of the induction type, to steel-mill work. He spoke of the development of the mill type motor and of the use of extremely large motors of 6,000 and 2,000 h.p. capacity in the Gary works. Mr. J. R. Ong also contributed to the discussion.

ST. LOUIS SECTION

The forty-fifth meeting of the St. Louis Section was held on February 10, 1909, with an attendance of 58 members and guests, Professor A. S. Langsdorf in the chair. The meeting was addressed by Professor Francis E. Nipher, of Washington University, on " Momentum Effects of Electrical Discharges." Professor Nipher has been experimenting for several years along new lines, and the results already obtained show quite conclusively that electricity has momentum, and therefore must have mass. The experiments consisted of passing an electric current around a sharp right angle in a conductor, and exposing photographic plates at the angle. Various conditions were imposed in the experiments, some of which showed conclusively that the effects were not produced by radio-activity. The results obtained are best explained by assuming that electricity has mass and momentum. These experiments have attracted the attention of scientists and engineers all over the world. Some months after Professor Nipher had announced the results of his experiments a scientist in Germany who had worked entirely independently announced the results of experiments which he had been carrying forward and which showed the same effects. A large number of lantern slides made from the photographic plates used in the experiments were shown. In the ensuing discussion several interesting points were brought out. A social hour followed the adjournment of the meeting, during which light refreshments and cigars were served.

At the forty-sixth meeting, held on March 10, 54 members and guests were present. The subject for the evening, "Alternating Current Commutator Motors", was presented by Mr. V. A. Fynn, electrical engineer, of England. Mr. Fynn has made a special study of this type of motor, and discussed it from the same standpoint as the direct-current motor. The commutator type of alternating-current motor was classed with the series direct-current motor, and the induction type of motor with the shunt direct-current motor. Various diagrams showing different windings of both direct- and alternating-current motors were explained, and the advantages and disadvantages of each were brought out. An interesting discussion followed the conclusion of the paper.

SAN FRANCISCO SECTION

The San Francisco Section held its regular monthly meeting in the building of the Pacific Gas & Electric Company, on March 26, 1909. A paper was presented by Mr. A. G. Jones descriptive of the use of the electrolytic lightning-arrester as a protection to high-voltage systems. The paper was illustrated with lantern slides. Many points regarding the use of the arrester were brought out in the discussion, and a sample arrester, such as is used on lines carrying a potential of 12,500 volts, was exhibited. Chairman C. W. Burkett presided at the meeting. Sixty-seven members were present.

SCHENECTADY SECTION

On February 18 Mr. E. F. Alexanderson read a paper before the Schenectady Section on "Alternating-Current Railway Motors". Mr. Alexanderson discussed in detail the different types of alternating-current railway motors, and by large free-hand drawings illustrated the various constructions used in America and abroad. He pointed out very concisely the relative advantages and disadvantages of the constructions found in the present day designs, without attempting to favor any particular design. After a detailed description of the motors Mr. Alexanderson took up their adaptability to railway service to meet the diversified conditions found throughout the country. He dwelt at some length on a comparison of single-phase and polyphase systems, and differentiated between the service conditions where either of these systems could be used to advantage.

The attendance was about 250, and the interest which those present took in the subject was clearly demonstrated by the large number of questions asked Mr. Alexanderson at the conclusion of his talk.

On February 25 Richard Fleming, of Lynn, Mass., lectured before the Section, on "The Electric Arc". Mr. Fleming has for a number of years been identified with the development of various arc lighting systems and has also carried on a great deal of work in connection with the arc furnace. Mr. Fleming's lecture covered particularly the peculiar phenomena existing in the arc, but did not describe the mechanism of arc lamps or arc furnaces. He illustrated graphically the characteristics of the carbon arc, flame arc, metallic arc, and the heavier arcs used in electric furnaces.

He analyzed in detail the shape, peculiarities and resistance of the arc at different points in its travel from one electrode to another, and at the conclusion of his paper illustrated by wave-form drawings the so-called power-factor phenomenon of the arc and its effect in distorting wave-forms. He gave a synopsis of the various theories which had been advanced in explanation of the properties of the arc, and pointed out the incompleteness of each of the theories and how much remained to be accomplished in advancing a theory which would satisfactorily explain all the phenomena of the arc.

The weather conditions were very unfavorable for a large attendance, but about 200 members were present and participated in the interesting discussion at the close of Mr. Fleming's talk.

At the meeting of March 11 the committee on papers decided to introduce an innovation, and accordingly arranged what they called a " Question and Answer " meeting. The membership had been duly notified and asked to send in advance questions which members desired to have answered, or subjects on which they would like to have a discussion. The committee was somewhat uncertain as to whether such a meeting would prove of general interest or not. It was an agreeable surprise therefore to have a hearty response in the way of a collection of so many questions that it was impossible to arrange to have a discussion of all of them at one meeting. Not only was the number of questions propounded large, but they were all sensible and logical, concerning matters of great interest to electrical engineers, and indicated that the members had considered them very seriously.

The meeting was not so largely attended as some of the other meetings, the attendance being about 75, but it was by far one of the most successful meetings ever held by the Section. The meeting began promptly at the usual hour, 8 o'clock, but proved so interesting that the membership would not consider an adjournment until after 11 o'clock. The experiment will undoubtedly be repeated in next year's course of lectures.

At the meeting of March 25 Mr. D. B. Rushmore presented an interesting paper before the Section, on the subject of " Electricity in Steel Mills ". Mr. Rushmore, as chief engineer of the power and mining department of the General Electric Company, has been afforded unusual opportunity to investigate the application of electricity to the steel industry, and his lecture was admirably arranged to bring out the significant points of this phase of electrical application. He showed a number of lantern slides tracing the evolution of the manufacture of steel from the time the ore is taken from the ground, up to the time when it is sent out as a finished product. He devoted especial attention to a detailed description of the Gary plant, illustrating how universally electricity is being applied in this most modern steel plant. Incidentally Mr. Rushmore took advantage of the opportunity to discuss at some length the relative merits of gas engines and steam turbines, and also the subject of the preservation of our natural resources. About 150 members heard Mr. Rushmore's talk.

SEATTLE SECTION

The industrial power meeting of this Section, held on March 20, was very successful. The first business was a report from the committee on entertainment of visiting engineers, a committee which was appointed in connection with the coming Alaska-Yukon-Pacific Exposition .A letter was read from Mr. Dunham, of the A. Y. P. Board, stating that June 10 had been set aside as " A.I.E.E. Day " at the big fair, and was favorably received by the members of the Section. At the conclusion of the business, Mr. C.

Remschel was introduced, and spoke on the subject of "Electric Drive in the Sawmill." Mr. Remschel gave a practical talk on the way in which electricity is displacing steam for sawmill drive. Among the advantages of motor drive, he cited:

a. Less insurance required, or none, because boilers and mill can be kept a safe distance apart.

b. More reliable operation because electric drive shows considerably fewer plant shut-downs.

c. Elimination of loss in belting, shafting and other transmission gear; elimination of wages of oiler for same. Mr. Remschel stated that in some cases he had observed, the friction load alone was 75 per cent of the total.

d. Lighting of the work. This is almost always necessary, and where electric drive is used necessitates very little extra expense.

The largest installation of motors for a single mill was 550 kw., and the largest single unit was a 250 h.p. motor used for driving a 9-ft. band saw. In connection with this latter item, Mr. Remschel cited the somewhat remarkable fact that the flywheel effect of a 9-ft. band saw was sufficient to carry it twice through a 40-ft. log with an 18 to 20 in. cut. As proving the more constant torque of motor-drive as compared with engines, Mr. Remschel stated that one large mill had not broken a single saw in two years' operation after installing electric drive. Following the main paper, the members discussed the subject and also the various phases of industrial motor application in the northwest. About 40 were present at the meeting.

SYRACUSE UNIVERSITY BRANCH

The second March meeting of this Branch was held on the evening of March 18. Mr. H. E. Nichols presented the Institute paper "Log of the New Haven Electrification."

On the evening of April 1, Mr. F. R. Kilcoyne presented an abstract of Mr. B. R. Shover's Institute paper on "The Industrial Application of the Electric Motor." The paper was discussed informally. Mr. Webb spoke briefly on the application of motors in paper mills and textile mills.

TOLEDO SECTION

The regular monthly meeting of the Toledo Section was held Friday evening, April 2, 1909, in the Builders' Exchange. Stormy weather prevented the usual good attendance. Mr. W. E. Richards abstracted the Institute paper by Mr. Shover, on "The Industrial Application of the Electric Motor." The paper was discussed during the course of the reading, as the various items were taken up.

TORONTO SECTION

The Toronto Section held its regular monthly meeting on March 19, with Mr. W. A. Bucke in the chair. A decided and growing interest has been manifested in the meetings of the Section in Toronto, which culminated in the largest attendance that this Section has yet enjoyed. A conservative estimate would place the attendance between 160 and 180 members and visitors, the lecture room of the Engineers Club being taxed to its utmost capacity. Previously to the meeting over 50 members and their friends enjoyed an informal luncheon at the St. Charles Cafe. The meeting was called to order at 8:30 p.m., and the chairman introduced Mr. Charles F. Scott, of Pittsburgh, who delivered an address on "Development of Apparatus for Power Transmission." Mr. Scott's address was rather of a semi-historical nature. He began with an informal talk on the present status of the Institute, the great importance to the membership of the Sections which have been established in the various cities throughout the country, concluding with a resumé of the work which has been done by the Institute in the matter of power transmission, referring particularly to that done by the High-Tension Transmission Committee. Mr. Scott then began his address proper with a review of the evolution of the transformer from its earliest types. He described some of the first transformers built and told of the necessary change in design required by the larger capacities and higher voltages demanded by the requirements of longer distances in power transmission. After discussing this matter very fully, he showed a number of lantern slides covering a great variety of the apparatus, in its earliest types to the very latest. These illustrations began with various photographs of early types of transformers, together with a number of photographs of recent design in high-voltage transformers, after which were shown illustrations of recent developments in single-phase locomotives, trolley-line construction, etc. A number of slides were then shown of various types of motors adapted to particular work. Then returning to his subject, Mr. Scott explained from the last slides shown, the different field which was opening for the development of power transmission, his argument being that the development of the use of power must come right along with the development of power transmission, the two going together. The adaptation of electric power to new conditions is one of the great features of this problem. He called particular attention to the fact that the electrical engineers of to-day must give more attention to the actual work to be done by the electric motor equipment than heretofore.

"Our problem is only half solved when we have got our power ready to apply. Those who look upon the application of electric power merely as a cheaper substitute for the steam engine, take a very narrow view. If all the electric motor could do would be to cheapen the cost per horse power at the shaft, it would do very little of what can be done. The steam engine is greatly limited; it must have its definite position; it has fairly definite speed; it is economical in large powers. The electric motor is simple and flexible, can be made in any size, put in any position, and adapted to its work. Formerly the manufacture of motors ranged from 10 h.p. to 75 or 100 h.p. To-day the manufacturer, instead of showing one page of motors, will give a whole catalogue; motors of variable speed, of all types and kinds, and of different mechanical form adapted to the machines they drive."

The electrical engineer is a kind of missionary. He revolutionizes methods, he changes the entire motive power of railways, and has made possible the more extensive use of tunnels under both land and water. In driving machinery the electric motor gives 65 per cent efficiency. The problem is not the saving of power, but making machines do their work better. In a large factory to-day the cost of power is only about two per cent of the cost of labor; therefore, if by applying twice as much power the output of that labor could be increased by even five per cent or 10 per cent, it would be economy to do it. The first cost of the motor is, in round numbers, equal to the amount of power consumed each year, and the interest per year on the cost of motors is therefore trifling. Therefore, if the motor can do the work more efficiently, and if the ease of adjustment of speed is such that the workman can apply the proper speed at the right time in such a way as to increase the output by one, two, or 10 per cent, a factory can then well afford to pay two or three times as much for an electric motor.

The address was followed by a spirited discussion, in which the following named gentlemen participated: Messrs. P. W. Sothman, J. S. Richmond, Julian Smith, V. G. Converse, K. L. Aitken, H. U. Hart, John Murphy, and Professor Rosebrugh.

URBANA SECTION

The March meeting of the Urbana Section was held in the electrical laboratory, University of Illinois, Wednesday, March 31, 1909, at 7:30 p.m.

An abstract of Mr. A. V. Reynder's paper on "Condenser Terminals" was presented by Mr. E. V. Camp. In discussing the paper Professor Paine showed the similarity between the design of condenser terminals and some problems in mechanical design where the proper placing of a smaller amount of metal will result in a stronger member than that obtained by using a much larger amount of metal. Professor Paine also gave a detailed explanation of the voltage distribution through a dielectric. Professor Brooks told about seeing some of those terminals in course of construction and of the materials which composed the terminals. Mr. Bryant spoke of the difficulty experienced in obtaining a satisfactory terminal for high-voltage work and told about the high-tension transformers built at the Worcester Polytechnic Institute. He also spoke of the corona and its possible effect on the insulation. The terminal makes possible higher potentials for transmission lines.

Professor Waldo presented an abstract of the paper by Dr. Rice on "Development of the General Electric Company." His connection with the Thomson Houston Company in 1892 enabled Professor Waldo to introduce personal reminiscences which gave an additional interest to the paper. He stated that it required but 10 years to antiquate every piece of electrical apparatus with the exception of the arc switchboard and the integrating wattmeter. Professor Brooks in his comments on the paper brought out the fact that he had been in charge of the first electrically lighted car operated on the railroad between New York and Boston. Mr. Bryant spoke of the rapid development in the electric industries at the present time and thought that it compared very favorably with the development between 1880 and 1890.

WASHINGTON D. C., SECTION

An industrial power meeting was held by the Washington Section on March 9. Twenty-nine members were present. Mr. R. Neil Williams, of Baltimore, Md., presented the subject, "Industrial Power Economy", and the reading of the paper was illustrated by a number of lantern slides. Mr. Williams went into the subject in detail, presenting it in an able and interesting manner. The paper was followed by a brief discussion.

WORCESTER POLYTECHNIC INSTITUTE BRANCH

This Branch held a meeting on March 12, at which Mr. M. V. Ayres gave a lecture on "Some Engineering Problems in Electric Railroading." The chief problem was the efficiency of transportation as affected by the weight of the car. Speed time curves were clearly dealt with, and the distribution of the losses in transportation were shown. Mr. Ayres laid particular stress on the saving that might be accomplished by the use of lighter weight cars, without much, if any, sacrifice in other directions. Seventy-five members were present.

The next meeting of the Branch was held on March 26, and there was an attendance of 190. Mr. W. S. Murray, of the New York, New Haven & Hartford Railroad, spoke on "Electrification." Mr. Murray pointed out wherein the conditions of the New Haven road were different from those of the New York Central. He said that electrification was not essentially new, but was simply a new chain composed of old links; the only new link, perhaps, being the single-phase motor. The construction of the New Haven road was very clearly shown by a collection of excellent slides which dealt with the power-house, steel structures and their erection, catenary suspension and cross-overs, sectionalization by means of oil switches, car parts, truck construction, etc. In closing, Mr. Murray summed up the important features of the road and told what the determining factors had been.

Personal

Mr. Arthur E. Tremaine recently accepted a position in the engineering office of the Eastern Concrete Construction Company Boston, Mass.

Mr. John W. Freeman has been appointed manager of the Sprague Electric Company's Pittsburgh office, to succeed Mr. F. W. Barry, who recently resigned.

Mr. James A. Sharp has left the Edison Illuminating Company of Detroit to take a position as traveling demonstrator for the Linman Protector Company of the same city.

Mr. F. F. Fowle, consulting electrical and telephone engineer, has removed from his offices, Room 736 Marquette Building, Chicago, Ill., to Room 937 in the same building.

Mr. Sidney W. Farnsworth, electrical engineer, has accepted a position as assistant electrical engineer with the Underwriters' Laboratories, 382 East Ohio Street, Chicago, Ill.

Mr. Kogoro Watanabe has lately severed his connection with Mitsui & Company, and established a consulting engineering and patent office at 12, sanchome Kobikicho Kyobashi, Tokyo, Japan.

Mr. E. E. Hinrichsen, who has been in the equipment engineering department of the Western Electric Company at Chicago, has recently been transferred to the New York office of the same company.

Mr. G. H. Fournier, associated with the Baltimore office of the Westinghouse Electric & Manufacturing Company for the past two years as erecting engineer, has been transferred to the Cincinnati office of the same company.

Mr. Henry A. Lardner, for many years on the New York staff of J. G. White & Company, has taken charge as manager of a branch office of that company which has just been opened in the Alaska Commercial Building, San Francisco, Cal.

Mr. T. A. Nichols severed his connection with the Allis-Chalmers Company a year ago to accept the management of the Kansas City office of the C. & G. Cooper Company, and on March first was transferred to that office.

Mr. C. G. Throckmorton, formerly connected with the signal department of the Union Pacific Railway, is now engaged with the engineering department of the Nebraska Telephone Company, Omaha, Nebraska.

Mr. Henry L. Davisson has resigned his position as assistant engineer of storage batteries with the New York Edison Company, to go with the Westinghouse Machine Company. He assumed his new duties on April 15.

Harry W. Tobey. the popular and efficient Local Secretary of the Pittsfield Section, is receiving the congratulations of his numerous friends upon his engagement with Miss Daisy B. Ritchie, of Bennington, Vermont, which was recently announced.

Mr. W. D. McDonald has succeeded Mr. T. Julian McGill as manager of the Minneapolis office of the Westinghouse Electric & Manufacturing Company, Mr. McGill having been made manager of the Atlanta, Ga. office of the same company.

Mr. Warren Partridge has resigned his position as assistant chief engineer of the Public Service Corporation of New Jersey, to accept the position of general superintendent of Springfield Railway and Light Companies, Springfield, Illinois.

Mr. F. C. Stieler, who has been with the Westinghouse Electric & Manufacturing Company at East Pittsburgh for the past three years, is now connected with the Pennsylvania Terminal & Tunnel Railroad Company, 10 Bridge Street, New York City.

Mr. A. S. Wattson, who returned from Rio de Janeiro, Brazil, last spring, and recently installed the central power house, U. S. Navy Yard, Charleston, S. C., is now installing a complete mining installation for the reduction of nickel ore, at Webster, N. C.

Mr. F. J. Southerland has been appointed assistant manager, engineer, and purchasing agent, for the Monterey County Gas & Electric Company, with which company he has been associated for the past two years. His office will be at Monterey, Cal.

Professor Henry H. Norris, of Sibley College, Cornell University, was elected on April 3 by the board of trustees of the university to the headship of the electrical department. Since Professor Ryan's resignation in 1905 Professor Norris has acted as head.

Mr. John R. Anderson, Jr., who for some years past has been on the engineering staff of the General Electric Company in its Pittsfield and Great Barrington works, has taken a position as assistant to the manager of the Edison Phonograph Works, West Orange, N. J.

Mr. C. B. Keiser, formerly assistant electrical engineer of the West Jersey & Seashore Railroad, has been appointed master mechanic of the Pennsylvania Tunnel & Terminal Railroad Company, with an office at the new terminal, 7th Avenue and 32nd Street, New York City.

Mr. J. E. Fries, formerly electrical engineer of the contract department of the Allis-Chalmers Company, and lately connected with the Canadian General Electric Company, has returned to this country and entered the employ of the Crocker-Wheeler Company, Ampere, N. J., as an electrical engineer.

Mr. Thomas F. Judge, lately electrical engineer, St. Croix Paper Company, Woodland, Maine, is now at Grand Falls, Newfoundland, to install electrical machinery for the Anglo-Newfoundland Development Company—about 8,000 h.p. hydraulic—where he expects to remain for a year.

Mr. A. J. Faulder, resigned on March 27, 1909, his position of engineering assistant in study department of N. Y. & N. J. Telephone Company, to accept the position of inspector of light and power, in Borough of Richmond, in the department of water supply, gas and electricity, New York City.

Mr. T. W. Simpson, formerly assistant to the superintendent of distribution of the Lowell Electric Light Corporation, has been transferred to Whitman, Massachusetts, to take charge of the Whitman branch of the Edison Electric Illuminating Company, of Brockton, Mass.

Mr. E. S. Lytch, chief electrician of the Prairie Pebble Phosphate Company, Mulberry, Fla., and formerly of the Westinghouse Electric & Manufacturing Company, has now become interested in the Laurinburg Machinery & Electrical Company, Laurinburg, N. C., which will hereafter be his headquarters.

Mr. R. H. Zavitz, who for a number of years has been associated with the sales organization of the Allis-Chalmers-Bullock, Ltd., Montreal, Canada, as district manager at Winnipeg and Vancouver, has recently been transferred to the Allis-Chalmers Company, as district manager of the Minneapolis office.

Mr. Harry O. F. Bindemann, electrical engineer, formerly of Essen-Ruhs, Germany, has given up his position as chief engineer to the Rhinisch-Westfalian Electricity Works at that city, and has associated himself with the Siemens-Schuckert Works and the Siemens-Halske Company, both in Berlin and in Havana, Cuba.

Mr. Henry C. Walter, formerly instructor in electrical engineering at the Worcester Polytechnic Institute, and later with Viele, Blackwell & Buck, has recently accepted the position of acting professor of physics and electrical engineering at the North Carolina College of Agriculture and Mechanic Arts.

Mr. R. H. Halpenny has resigned his position with the Ames Engineering Company, Ames, Iowa, as superintendent of the testing department, and taken a position with the Nevada-California Power Company, as assistant superintendent of the Silver Peak and Blair installations, with headquarters at Silver Peak, Nevada.

Mr. Charles G. Edwards, until lately assistant engineer to the Electrical Commission of Baltimore City, and local secretary of the Baltimore Section of the Institute, has entered the service of the Pennsylvania Tunnel & Terminal Railroad Company at New York, as assistant superintendent of construction, electric traction.

Mr. L. L. Newman was transferred on April 1 from the motive power department of the Pennsylvania Railroad Company, Altoona, Pa., to the office of chief engineer, East River division, Pennsylvania Tunnel and Terminal Railroad Company, New York City, in connection with motive power facilities for Sunnyside Yard, Long Island.

Mr. M. Berthold recently terminated his connection with the Fairbanks-Morse Electric & Manufacturing Company, of Indianapolis, Ind., the electrical department of Fairbanks, Morse & Company, of Chicago, as engineer and designer of their direct- and alternating-current machinery, which position he held for over four years.

Mr. Lloyd E. Knapp, formerly general manager of the Fort Worth Telephone Company, Fort Worth, Texas resigned his position with that company last August to enter the electrical engineering field in the southwest. An engineering company has been formed with offices in the Binz Building, Houston, Texas, under the name, Lloyd E. Knapp & Company, of which Mr. Knapp is president and general manager.

Mr. M. H. Voss, who for the past year has been with the Cia Carbonifera de Lampacitos, as electrical engineer, supervising the electrification of their mines, left them in March to engage in a general engineering and contracting business in Sabinas, Coahuila, the center of the coal mining district. A number of the mines are preparing to operate electrically, getting their power from the waste heat of the coke-ovens.

Mr. C. G. Winslow, formerly with the New York Central & Hudson River Railroad Company, electrical department, and later with Viele, Blackwell & Buck as construction engineer, is now with the Interurban Company, 25 Broad Street, New York. At present Mr. Winslow is engineer in charge of the construction of eight miles of street railway which the Interurban Company is building for the Burgrahaw Traction Company, at Burlington, N. C.

Mr. William D. Ligon recently resigned his position as engineer-salesman with the Westinghouse Electric & Manufacturing Company, of East Pittsburgh, Pa., to become manager of works for the D. & W. Fuse Company, of Providence, R. I. Mr. Ligon was associated with the Westinghouse Company for eight years in various positions, and for the last three years was located in Syracuse, N. Y., in charge of central station work and large power developments.

Mr. William A. Baehr, for a number of years chief engineer of the Laclede Gas Light Company, of St. Louis, Mo., has gone into business as a consulting engineer, with an office at 1943 Commercial National Bank Building, Chicago, Ill. Mr. Baehr will devote particular attention to the field of gas engineering, as well as electrical work, such as power plants, distribution systems, etc., and has made arrangements to represent Bartlett, Hayward & Company, of Baltimore, Md., in the West.

Accessions to the Library

The following accessions have been made to the Library of the Institute since the last acknowledgment:

The A. B. C. of Wireless Telegraphy. By Edward Trevert. Lynn, Bubier Publishing Company, 1907. $1.00.

American Telephone and Telegraph Company. Annual Report of the Directors to the Stockholders, 1908. Boston, G. H. Ellis Co., 1909. (Gift of T. N. Vail.)

Berichte der Deutschen Physikalischen Gesellschaft. Year 2-date. Braunschweig, 1909-date. (Purchase.)

Bill of Complaint. The United States Telephone Company vs. Central Union Telephone Company and American Telephone and Telegraph Company. No place, no date. (Gift.)

Care and Repair of Dynamos and Motors (Machinery's Reference Series No. 34.) New York, Industrial Press, 1909. 25c.

Carnegie Institution of Washington, Department of Terrestrial Magnetism. Annual Report of the Director 1908. No place, no date. (Gift.)

Connecticut-Bureau of Labor Statistics. Report 23d. Hartford, 1908. (Gift.)

Discussion of Telephone Competition. By J. H. Ainsworth and G. R. Johnston. Columbus, Berlin Printing Company, 1908. (Gift of Ohio Independent Telephone Association.)

Electric Lamps. By Maurice Solomon. New York, D. Van Nostrand Company, 1908. (Gift of publishers.) $2.00 net.

Contents.—Chapter I.—Principles of Artificial Illumination. II.—Production of Artificial Light. III.—Photometry. IV.—Methods of Testing. V.—Carbon-Filament Lamps. VI.—The Nernst Lamp. VII.—Metallic-Filament Lamps. VIII.—The Electric Arc. IX.—Manufacture and Testing of Arc Lamp Carbons. X.—Arc Lamps. XI.—Miscellaneous Lamps. XII.—Comparison of Lamps of Different Types.

Electric Telegraph. Part I—By Charles Thom; part II-Wireless telegraphy. By A. F. Collins. Chicago, American School of Correspondence, 1908 $1.00.

Electrical Field. Monthly. Volume 1, numbers 5 & 7, London, 1908. (Gift of McGraw Publishing Company.)

Heavy Electrical Engineering. By H. M. Hobart. New York, D. Van Nostrand Company, 1908. (Gift of publishers.) ($4.50 net.)

Contents.—Chapter I.—Introductory. II.—The Overall Efficiency of Generating Stations and the Relation between Coal Consumption and Outgoing Electrical Energy. III.—Steam Raising Plant. IV.—Piston Engines and Steam Turbines. V.—Condensing Plant. VI.—Electric Generating Plant. VII.—Design of Generating Stations. VIII.—High Tension Power Transmission Lines. IX.—High Tension Continuous Current Series System. X.—Electric Traction Calculations. XI.—Traction Motors and Electrification of Railways. Appendix.

Forest Working Plan for Land Belonging to the City of Fall River on the North Watuppa Watershed. By Massachusetts Forest Service. Boston, Wright & Potter Printing Co., 1909. (Gift.)

Hertzian Wave Wireless Telegraphy. By J. A. Fleming. No place, no date. $1.50.

L'Industrie des Tramways et Chemins de Fer. Revue mensuelle. 2e Anneé, numbers 1, 2 & 6. Paris, 1908. (Gift of McGraw Publishing Company.)

Interstate Commerce Commission. Annual Report 22d. Washington, U. S. Government, 1909. (Gift.)

Jahrbuch der Drahtlosen Telegraphie und Telephonie. Volume I. von Jonathan Zenneck und Gustav Eichhorn. Leipzig, J. A. Barth, 1908. (Purchase.) $5.50.

Kansas Gas, Water, Electric Light and St. Railway Association. Proceedings, 1908. Pittsburg, 1908. (Gift.)

Lectures on Electric Traction for Railway Trains. By E. P. Burch. Minneapolis, 1909. (Gift of author.)

Michigan Electric Association. Proceedings of the Annual Convention. 1st–5th. Various places, 1904–1908. (Gift of Michigan Electric Association.)

Necessity for Government Aid to Reestablish an American Merchant Marine for Extension of Foreign Markets and an Adequate Naval Reserve. Speech of J. S. Fassett, March 2, 1909. Washington, 1909. (Gift.)

Ohio Independent Telephone Association. Bulletin volume 1, numbers 6, 10–12; volume 2, numbers 1–4. Columbus, 1908–1909. (Gift of Ohio Independent Telephone Association.)

Opinion of the Commission in the Matter of the Application of Erie Railroad Company, under section 55 of the Public Service Commissions law, for authority to issue its five per cent collateral gold bonds to the amount of $30,000,000. Submitted January 5, 1909. No place, no date. (Gift of Public Service Commission of the Second District of the State of New York.)

Principal Facts of the Earth's Magnetism. Washington, U. S. Government, 1909. (Gift of the U. S. Coast and Geodetic Survey.)

Railroads and the Smoke Nuisance. By C. R. Woodruff. (Gift of American Civic Association.)

Return on the Investment in the Subway of the Interborough Rapid Transit Company of New York City. Report No. 7, 1908. New York, 1908. (Gift of Public Service Commission for the First District of the State of New York.)

Rules of Practice of the Public Service Commission Second District of the State of New York. Albany, J. B. Lyon Company, 1907. (Gift of State of New York Public Service Commission.)

Significance of drafts in steam-boiler practice. (Bulletin no. 367, U. S. Geological Survey.) By W. T. Ray and Henry Kreisinger. Washington, U. S. Government, 1909. (Exchange.)

Some Comments on the 1907 Annual Report of American Telephone and Telegraph Company. By G. R. Johnston. Columbus, Berlin Printing Company, 1908. (Gift of Ohio Independent Telephone Association.)

State of New York Public Service Commission, Second District. Annual Report 1st, volumes 1–2; 2d. Albany, 1908–1909. (Gift of State of New York Public Service Commission.)

Telephone Construction Methods and Cost. By Clarence Mayer. Chicago-New York, Myron C. Clark Publishing Co., 1908. (Gift of publishers.)

CONTENTS.—Chapter I.—Methods and Cost of Pole Line Construction. II.—Methods and Cost of Cable Construction. III.—Methods and Cost of Cable Splicing. IV.—Methods and Cost of Removing old Line and of Reconstruction. V.—Methods and Cost of Constructing Underground Conduit. VI.—Detailed Cost of Constructing 824, 862 Duct Feet of Underground Conduit and 318 Vaults in One Job. VII.—Miscellaneous Costs and Special Data. VIII.—The Practice of Estimating. Appendix A.—Cost of Materials and Labor in Constructing Telephone Line. Appendix B.—Miscellaneous Cost Data on Pole Line and Underground Conduit Construction. List of Tables.

Theory of Electric Cables and Networks. By Alexander Russell. New York, D. Van Nostrand Company, 1909. (Gift of Publisher.) ($3.00 net.)

CONTENTS.—Chapter I.—Fundamental Principles. II.—Conductivity. III.—Insulativity. IV.—Distributing Networks. V.—Insulation Resistance of House Wiring. VI.—Insulation Resistance of Networks. VII.—Faults in Networks. VIII.—Dielectric Strength. IX.—The Grading of Cables. X.—The Heating of Cables. XI —Electrical Safety Valves. XII.—Lightning Conductors.

Wireless Telegraphy. By Gustav Eichhorn. London, Charles Griffin & Co., 1906. $2.75.

Wireless Telegraphy and Hertzian Wave Edition 3. By S. R. Bottone. London-New York, Whittaker & Co., 1905. $1.00.

Wireless Telegraphy and Telephony. Compiled by Maurice Ernst. London, no date. 50c.

Wireless Telegraphy and Telephony. By Domenico Mazzotto. Translated from the original Italian by S. R. Bottone. London-New York, Whittaker & Co., 1906. $2.00.

Wireless Telegraphy for Amateurs. By R. P. Howgrave-Graham. New York, Spon & Chamberlain. No date. $1.00.

Wireless Telegraphy Popularly explained. Edition 6. By Richard Kerr. London, Seeley & Co., Ltd., 1903. 75c.

Yearbook of Legislation of the New York State Library, 1907. Albany, University of the State of New York, 1908. (Gift.)

Zeitschrift für Schwachstromtechnik. Year 3-date. München, 1909-date. (Purchase.)

Trade Catalogues

Collins Wireless Telephone Co., Newark, N. J. The Collins Bulletin vol. I, No. 2, October, 1908.

——Transformer versus Induction Coils. Vol. I, No. 3. November, 1908, cont.

——The Development of the Coherer, by A. F. Collins.

——Brauly's New Electrolytic Detector, by Henri Ruinart. Vol I., No. 4. December, 1908.

——Knudsen Wireless Photogram, by A. C. Kopp.

——A New Aluminum Rectifier, by Henri Ruinart.

List of Articles by A. F. Collins on Wireless Telegraphy, Wireless Telephony, and other subjects.

Collins Wireless Telephone Co., Newark, N. J., Collins Wireless Bulletin for January, 1909. Containing The Underhill Wireless Typewriting System, by Wm. J. White; The design and construction of Wireless Telegraph Sets, by A. F. Collins.

——Bulletin for February, 1909, containing Artoni Directive Wireless Telegraph System, translated from the original of Count Alessandro Artoni by S. Valentine.

——Wireless electric lights, by Wm. Dubilier.

Design and Construction of Wireless Telegraph sets, by A. F. Collins.

Collins Wireless Telephone Company, 54 Clinton Street, Newark, N. J. Price List of the Collins Wireless Telegraph Sets. Illustrated Catalogue, pts. 1–2. 1908.

Crocker-Wheeler Company, Ampere, N. J. Numerical Index to Live Bulletins. January, 1909.

——List of Engine Type Direct Current Generators. (Bulletin no. 110.)

Duncan Electric Manufacturing Company. Lafayette, Ind. Direct Current Integrating Wattmeter. (Bulletin no. 8). Jan. 1909.

Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa. Fault Finder.

——Factory Cable Testing Apparatus.

Leeds & Northrup Co., Philadelphia, Pa. Resistance boxes with metal and wooden spools.

——Resistance spools for precision rheostats.

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——Leeds & Northrup Dial Decade Portable Testing Set.

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Sections and Branches—Directory.

SECTIONS	Organization authorized by Board of Directors	Chairman	Secretary
Atlanta	Jan. 19, '04	W. R. Collier	E. P. Peck, Box 52, Atlanta, Ga.
Baltimore	Dec. 16, '04	J. B. Whitehead	Charles E. Phelps, Jr., Acting Secretary, City Hall, Baltimore, Md.
Boston	Feb. 13, '03	A. E. Kennelly	A. L. Pearson, 93 Federal St., Boston, Mass.
Chicago	1893	W. L. Abbott	J. G. Wray, 203 Washington St., Chicago, Ill.
Cleveland	Sept. 27, '07	C. W. Ricker	F. M. Hibben, 1549 Winton Ave., Cleveland, O.
Columbus	Dec. 20, '03	R. J. Feather	H. L. Bachman, 1070 E. Fulton St., Columbus, O.
Fort Wayne	Aug. 14, '08	E. A. Wagner	J. V. Hunter, 506 W. Jefferson St., Ft. Wayne, Ind.
Ithaca	Oct. 15, '02	E. L. Nichols	B. C. Dennison, Cornell Univ., Ithaca, N. Y.
Los Angeles	May 19, '08	C. W. Koiner	J. E. MacDonald, 444 P. E. Bldg., Los Angeles, Cal.
Madison	Jan. 8, '09	C. E. Carter	J. W. Shuster, Univ. of Wisconsin, Madison, Wis.
Mexico	Dec. 13, '07	R. P. Hayward	F. D. Nims, Mex. Lt. & Pr. Co., Mexico, Mex.
Minnesota	Apr. 7, '02	Barry Dibble	J. C. Vincent, 1313 6th St., S. E., Minneapolis, Minn.
Norfolk	Mar. 13, '08	D. G. Stanbrough	R. R. Grant, P. O. Box 254, Norfolk, Va.
Philadelphia	Feb. 18, '03	Paul Spencer	H. F. Sanville, 1708 Sansom St., Phila., Pa.
Pittsburg	Oct. 13, '02	W. Edgar Reed	B. P. Rowe, 911 Ramsey Ave., Wilkinsburg, Pa.
Pittsfield	Mar. 25, '04	W. A. Hall	H. W. Tobey, General Electric Co., Pittsfield, Mass.
San Francisco	Dec. 23, '04	C. W. Burkett	S. J. Lisberger, 925 Fanklin St., San Francisco, Cal.
Schenectady	Jan. 26, '03	E. J. Berg	M. O. Troy, G. E. Co., Schenectady, N. Y.
Seattle	Jan. 19, '04	J. H. Harisberger	Geo. H. Moore, Rialto Court, Boylston Ave., Seattle, Wash.
St. Louis	Jan. 14, '03	A. S. Langsdorf	H. I. Finch, 5217 Morgan St, St. Louis, Mo,
Toledo	June 3, '07	C. R. McKay	Geo. E. Kirk, 1614 The Nicholas, Toledo, O.
Toronto	Sept. 30, '03	W. A. Bucke	W. H. Eisenbeis, 1207 Traders' Bank Bldg., Toronto, Can.
Urbana	Nov. 25, '02	E. B. Paine	E. I. Wenger, 911 W. California St., Urbana, Ill.
Washington, D. C.	Apr. 9, '03	Philander Betts	H. C. Eddy, 806 Westory Building, Washington, D. C.

Total, 24.

Sections and Branches—Directory.

BRANCHES	Organization authorized by Board of Directors	Chairman	Secretary
Arkansas, Univ. of....	Mar. 25, '04	C. R. Rhodes	F. S. White, 523 North Willow St., Fayetteville, Ark.
Armour Institute......	Feb. 26, '04	T. W. Simpson	J. E. Snow, Armour Inst. Tech., Chicago, Ill.
Case School, Cleveland	Jan. 8, '09	K. E. Norton	A. M. Klingman, Case School of App. Science, Cleveland, O
Cincinnati. Univ. of...	Apr. 10, '08	C. R. Wylie	C. A. Winder, 1332 Lincoln Ave., Cincinnati, O.
Colorado, Univ. of.....	Dec. 16, '04	H. H. Watters	L. D. Jones, Univ. of Colorado, Boulder, Colo.
Iowa State College....	Apr. 15, '03	Frank K. Shuff	M. W. Pullen, Iowa State College, Ames, Ia.
Kansas State Agr. Col..	Jan. 10, '08	W. L. Enfield	W. C. Lane, Kan. State Agr. Col., Manhattan, Kan
Kansas, Univ. of......	Mar. 18, '08	Ray Jones	E. J. Thiele, 1042 Tennessee Street, Lawrence, Kan.
Lehigh University.....	Oct. 15, '02	A. S. Garrison	R. F. Turner Lehigh Univ., Bethlehem, Pa.
Lewis Institute........	Nov. 8, '07	R. M. Walker	P. B. Woodworth, Lewis Institute, Chicago, Ill.
Maine, Univ. of.......	Dec. 26, '06		Gustav Wittig, Univ. of Maine, Orono, Me.
Michigan Univ. of....	Mar. 25, '04	H. F. Baxter	P. R. Moffett, 1335 So. State St., Ann Arbor, Mich.
Missouri, Univ. of.....	Jan. 10, '03	H. B. Shaw	H. D. Carpenter, Univ. of Missouri, Columbia, Mo.
Montana Agr. Col.....	May 21, '07	B. S. Hind	J. A. Thaler, Montana Agr. Col., Bozeman, Mont.
Nebraska, Univ. of....	Apr. 10, '08	Geo. H. Morse	L. E. Hurtz, Lincoln Tel. Co., Lincoln, Neb.
New Hampshire Col...	Feb. 19, '09	A. M. Buck	E. R. Fellows
Ohio State Univ......	Dec. 20, '02	F. W. Funk	F. C. Caldwell, Ohio State Univ., Columbus O.
Oregon State Agr. Col..	Mar. 24, '08	S. H. Graf	C. Christiansen State Agricultural College, Corvallis, Ore.
Penn. State College....	Dec. 20, '02	E. A. Wilcox	H. S Amer, Penn. State College, Pa.
Purdue Univ..........	Jan. 26, '03	J. W. Esterline	H. T. Plumb, Purdue Univ., Lafayette, Ind.
Stanford Univ........	Dec. 13, '07	W. C. North	A. J. Gowan, Stanford Univ., California.
Syracuse Univ.........	Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse Univ., Syracuse, N. Y.
Texas, Univ. of.......	Feb. 14, '08	A. C. Scott	B. E. Kenyon, Univ. of Texas, Austin, Tex.
Wash. State Col. of...	Dec. 13, '07	H. V. Carpenter	M. K. Akers, State Col. of Wash., Pullman, Wash.
Washington Univ.....	Feb. 26, '04	C. M. Duncan	H. F. Thomson, 5011 Washington Ave., St. Louis, Mo.
Worcester Poly. Inst..	Mar. 25, '04	F. A. Spencer	W. D. Stearns Worcester Poly. Inst., Worcester, Mass.

Total, 26.

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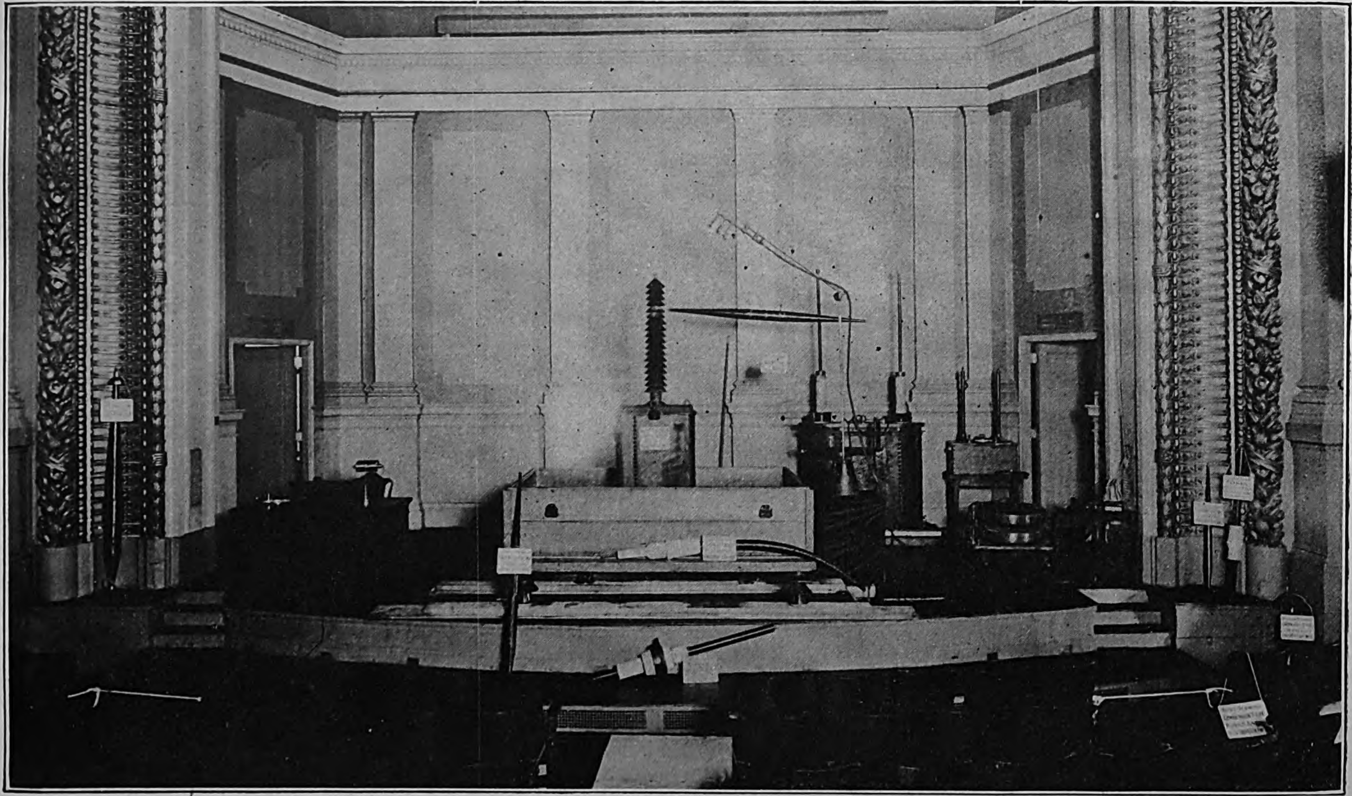

Apparatus used for testing condenser type of insulation for high-tension terminals to 225,000 volts
Auditorium of the Engineers' Building, New York, April 9, 1909

PROCEEDINGS
OF THE
American Institute
OF
Electrical Engineers.

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A. H. ARMSTRONG

GEORGE A. WARDLAW, Editor

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Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month.

Vol. XXVIII **June, 1909** No. 6

Report of Board of Directors

On pages 681–698 of this PROCEEDINGS will be found the annual report of the Board of Directors for the fiscal year ending April 30, 1909. This report consists partly of abstracts containing the gist of the more extended reports submitted by the nine standing committees and eleven of the special committees appointed in accordance with Article VII, Sections 41 and 46 of the Constitution. The reports of the Finance Committee and the Library Committee are printed in full. The report of the Finance Committee shows the monetary affairs of the Institute to be in excellent condition. The receipts per member were $13.21, or $0.20 greater than the receipts per member for the previous year. The disbursements per member were $10.49, or $1.24 less than the disbursements per member for the previous year. This indicates a net result on the credit side of $1.44 per member over that of 1908. The total credit balance per member on April 30, 1909, was $2.72. The total membership was 6400. The total excess of receipts over disbursement was, as shown on page 691, $17,424.13. The report of the Editing Committee states that Vol. XXVII of the TRANSACTIONS, consisting of the papers and discussions during the calendar year 1908, the report of the Board of Directors for year ending April 30, 1908, and the revised By-laws, will contain 1716 pages. The volume will be issued in two parts, each part containing 858 pages, and will probably be ready for distribution on September 1, 1909.

The Convention and the Constitution

In accordance with Section 62 of Article VIII of the Constitution, there shall be held outside of the city of New York, not later than August first, an annual convention of the Institute. At this convention, in addition to the presentation and discussion of professional papers, other matters of immediate interest to the members may be brought up for discussion, and may be referred, with recommendations, by a majority vote, to the Board of Directors. In granting the convention this privilege, however, the Constitution limits the power of a convention by stating, further, that no convention shall have the privilege of transacting any business that may affect either the policy or the organization of the Institute.

Convention Papers

The preliminary program printed on pages 2–4 of Section I of this PROCEEDINGS indicates that thirty-three papers will be presented at the next convention. One of these papers was published in the May PROCEEDINGS; ten more are published in this issue; the remaining papers, twenty two in number, will be published in the July PROCEEDINGS, to be issued not later than June 20.

Announcement of the Twenty-sixth Annual Convention, Frontenac, N. Y., June 28 to July 1, 1909

The Twenty-sixth annual convention of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS will be held at the Hotel Frontenac, Frontenac, Thousand Islands, N. Y., from June 28 to July 1, 1909.

Institute Headquarters

The Institute headquarters during the convention will be at the Hotel Frontenac. On arriving at the hotel, each member should register at the Institute headquarters and obtain an identification badge. The convention sessions will be held in the hotel.

PROGRAM*

Monday, June 28

MORNING SESSION—10 A.M.

1. LOUIS A. FERGUSON, President's Address.
2. A. E. KENNELLY, C. A. WRIGHT AND J. S. VAN BYLEVELT, "The Convection of Heat from Small Copper Wires."
3. E. F. W. ALEXANDERSON "Alternator for 100,000 Cycles."
4. L. W. CHUBB, "Method of Testing Transformer Core Losses Giving Sine-wave Results on Commercial Circuits."
5. M. G. LLOYD AND J. V. S. FISHER, "Testing of Transformer Steel."

AFTERNOON SESSION—2 P.M.

6. F. CREEDY, "A Sketch of the Theory of the Adjustable-Speed, Single-Phase, Shunt, Induction Motor."
7. E. F. W. ALEXANDERSON, "Repulsion Motor with Variable-Speed, Shunt Characteristics."
8. A. MILLER GRAY, "The Heating of Induction Motors."
9. S. V. CHARTERS, JR., AND W. A. HILLEBRAND, "Reduction in Capacity of Polyphase Motors Due to Unbalancing in Voltage."
10. A. S. LANGSDORF, "The Current Locus of the Single-Phase Induction Motor."

Tuesday, June 29

MORNING SESSION—10 A.M.

11. P. H. Thomas. "Output and Regulation in Long-Distance Lines."
12. P. H. THOMAS, "Calculation of the High-Tension Line."
13. J. B. TAYLOR, "Even Harmonics in Alternating-Current Circuits."
14. J. B. WHITEHEAD, "The Resistance and Reactance of Armored Cables."

Tuesday evening at 6 p.m. there will be a dinner and discussion by the Sections Committee and Section Delegates.

EVENING SESSION—8 P.M.

15. W. S. MOODY AND G. FACCIOLI, "Corona Phenomena in Air and Oil and their Relation to Transformer Design."
16. E. E. F. CREIGHTON AND S. D. SPRONG, "Surges on Cable Systems with Aluminum Cell Protection."
17. J. L. WOODBRIDGE, "Split-Pole Converters and Storage-Battery Regulation."

PARALLEL SESSION—TUESDAY 8 P.M.

18. H C. SPECHT, "Function of Flywheels in Connection with Electrically Operated Rolling Mills."
19. K. A. PAULY, "Alternating-Current Motors versus Direct-Current Motors in Steel Mills."
20. E. W. YEARSLEY, "Rolling Mill Motors."
21. E. FRIEDLANDER, "Electric Driven Rolling Mills."
22. B. WILEY, "Power Requirements for Rolling High-Carbon Steel of Small Section."
23. C. T. HENDERSON, "Electrical Control for Rolling-Mill Motors."

Wednesday, June 30

MORNING SESSION—10 A.M.

24. L. W. DOWNES, "Some Considerations in Designing Heavy-Capacity Fuses."
25. C. J. FECHHEIMER, "Comparative Costs of 25-cycle and 60-cycle Alternators."

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* **Sequence of papers and the dates assigned are subject to change.**

26. I. E. **Hanssen**, "Calculation of Iron Losses in Dynamo Electric Machinery."
27. J. N. **Dodd**, "Auxiliary Poles for Direct-Current Machines."
28. L. T. **Robinson**, "Electric Measuring Devices."
29. C. A. **Adams**, "Electromotive force Wave-Shape in Alternators."

Thursday, July 1

MORNING SESSION—10 A.M.

30. F. B. **Jewett**, "The Modern Telephone Cable."
31. C. A. **Adams**, (title of paper not yet announced.)
32. C. R. **Dooley**, "The Education of the Electrical Engineer."
33. C. P. **Steinmetz**, "The Value of the Classics in Engineering Education."

Entertainment

The Convention Committee announces the following social functions:

No entertainment has been planned for Monday afternoon, but boating, fishing, golf, croquet, and other outdoor pastimes will be available for those wishing to make use of them.

On Monday evening there will be a reception and dance at the Hotel Frontenac.

On Tuesday afternoon there will be a qualifying round in a handicap golf tournament. The first eight will qualify for the semi-finals. There will also be a women's putting contest, accompanied by first, second, and third prizes.

Tuesday evening there will be a women's bridge tournament.

Wednesday morning there will be a daylight excursion for women through the Thousand Islands on a large steamer. The semi-finals of the golf match and a driving contest will be held Wednesday afternoon.

Wednesday evening there will be a search-light trip of fifty miles among the islands on a large steamer for both men and women.

The finals of the golf tournament will take place Thursday afternoon.

In addition to first, second, and third prizes in the women's putting contest, the following prizes will be given: First prize for men in golf tournament, also runner-up prize in men's golf tournament. There will be prizes for the best net score and the best gross score, as well as first and second prizes in the driving contests.

There will also be first, second, and booby prizes in the women's bridge whist tournament.

Prizes will also be given for the largest fish caught during the convention and also for the largest "catch."

It is proposed to have available a number of launches, which can take small parties around the islands, these parties to be made up by the individuals wishing to take the boat rides. Application may be made to any member of the Convention Committee. Golf will be available for men and women at any time, as the golf links are adjacent to the hotel and are readily accessible. There is a fine nine-hole course. Individuals can obtain guides and rowboats at a minimum charge for fishing at any time. The fishing is excellent.

Transportation

The rate of fare and one-third on the certificate plan which has in previous years been granted by the passenger associations for members and guests attending conventions of the Institute and similar organizations, has recently been increased to a fare and three-fifths, and even this rate is applicable only to a limited territory.

The certificate plan limits the use of the return ticket to three days after the close of the convention and requires each passenger to go and return by the same route. This requirement would prevent many of the Institute members from taking advantage of the reduced rates, as, on account of the many delightful trips that may be taken in going to or leaving the Thousand

Islands, a considerable number will desire to go by one route and return by another.

After considering the above facts and other matters relating to transportation, it has been deemed inexpedient to make application for reduced rates on the certificate plan as heretofore. Practically all the transportation companies will have special summer excursion rates to The Thousand Islands in force at the time of the Institute convention. These rates are in general the most advantageous that can be obtained and, in most cases, are very little, if any, in excess of the rates that might be obtained under the certificate plan.

Members should, therefore, consult their local ticket agents regarding routes and rates, preferably several days before they intend to start for the convention.

Hotel Rates

Every member should arrange for his own hotel accommodations. Early application is desirable. Correspondence on this subject should be addressed to the Hotel Frontenac, Frontenac, New York. The management of the hotel has made the following rates, on the American plan, for members and guests attending the convention: $4.00 per day per person for room without bath, $5.00 per day with bath. The rate per day per person is the same whether one or two persons occupy a room.

Convention Committee, 1909

C. W. Stone, Chairman, Schenectady, N. Y.
A. W. Berresford, Milwaukee, Wis.
W. A. Bucke, Toronto, Canada.
Sidney Hosmer, Boston, Mass.
John W. Lieb, Jr., New York City.
J. C. McQuiston, Pittsburgh, Pa.
D. F. Schick, Philadelphia, Pa.
A. M. Schoen, Atlanta, Ga.
S. D. Sprong, New York.
Earl Wheeler, Washington, D. C.
J. C. Wray, Chicago, Ill.
L. S. Streng, Louisville, Ky.

Minutes of May Meeting of the Institute

The two hundred and thirty-seventh regular, and twenty-sixth annual meeting, of the American Institute of Electrical Engineers was held in the auditorium of the Engineers' Building, 33 West Thirty-ninth Street, New York City, Tuesday, May 18, 1909. President Ferguson presided, and called the meeting to order at 8 p.m. The secretary announced that at the meeting of the Board of Directors held in the afternoon 151 Associates were elected, and two Associates were transferred to the grade of Member. Those present at the directors' meeting were: President Louis A. Ferguson, Chicago, Ill.; Past-President Henry G. Stott, New York City; Vice-Presidents James G. White, New York; W. C. L. Eglin, Philadelphia, Pa., Calvert Townley, New Haven, Conn.; Managers Paul M. Lincoln, Pittsburgh, Pa., Paul Spencer, Philadelphia, Pa., William S. Murray, New Haven, Conn., Percy H. Thomas, New York, W. G. Carlton, New York, Charles W. Stone, Schenectady, N. Y., H. E. Clifford, Boston, Mass.; Treasurer George A. Hamilton, Elizabeth, N. J., Secretary Ralph W. Pope, New York. The secretary then presented the annual report of the Board of Directors, which on motion duly seconded was accepted. This was followed by the report of the Committee of Tellers on the election of officers of the Institute. The secretary announced that he had received 578 proxies, of which 503 were valid, constituting a legal quorum. The report of the Committee of Tellers follows·

To the President of the American Institute of Electrical Engineers:

Dear Sir: This committee has carefully canvassed the ballots cast for officers for the year 1909–1910. The result is as follows:

Total number of envelopes said to contain ballots, received from Secretary........	2,285
Rejected on account of bearing no identifying name on outer envelope, according to Article VI, Section 33 of the Constitution................	33

Rejected on account of voter being in arrears for dues on May 1, 1909, as provided in the Constitution and By-laws	99	
Rejected on account of ballot not being enclosed in inner envelope, or on account of inner envelope bearing an identifying name, according to Article VI, Section 33 of the Constitution	31	
Rejected on account of having reached the Secretary's office after May 1, according to Article VI, Section 33 of the Constitution	16	
		179
Leaving as valid ballots		2,106

These 2,106 valid ballots were counted and the result is shown below:

For President:

L. B. Stillwell	2,069
Ralph D. Mershon	21
J. G. White	11
E. J. Berg	2
Blank	3
	2,106

For Vice-presidents:

J. J. Carty	2,066
Paul M. Lincoln	2,053
Paul Spencer	1,951
E. J. Berg	71
A. M. Hunt	52
A. M. Schoen	43
Ralph D. Mershon	26
J. P. Jackson	15
W. S. Murray	3
W. S. Rugg	1
H. B. Smith	1
N. W. Storer	1
Blank	35
	6,318

For Managers:

A. W. Berresford	2,072
W. S. Murray	2,071
H. H. Norris	2,066
S. D. Sprong	1,981
H. B. Smith	67
N. W. Storer	34
Henry Floy	28
W. S. Rugg	17
J. F. Stevens	12
J. P. Jackson	2
E. J. Berg	2
A. M. Hunt	1
R. D. Mershon	1
Blank	70
	8,424

For Treasurer:

George A. Hamilton	2,096
Blank	10
	2,106

For Secretary:

Ralph W. Pope	2,091
F. L. Hutchinson	5
Blank	10
	2,106

Respectfully submitted,
W. I. DONSHEA,
Chairman.
F. MAGALHAES,
GEO. I. RHODES,
E. H. LE TOURNEAU,
Committee of Tellers.

The president announced officially the election of the following officers:

President,	LEWIS B. STILLWELL
Vice-Presidents,	JOHN J. CARTY PAUL M. LINCOLN PAUL SPENCER
Managers,	A. W. BERRESFORD W. S. MURRAY H. H. NORRIS S. D. SPRONG
Treasurer,	GEORGE A. HAMILTON
Secretary,	RALPH W. POPE

Mr. Frederick P. Fish, of Fish, Richardson, Herrick and Neave, of Boston, then presented a paper on "The Patent System in its Relation to Industrial Development." The paper was discussed by Messrs. F. B. Crocker, A. Goold Davis, Arthur van Briesen, E. W. Rice, Jr., Thomas B. Kerr, Edgar Bull, Livingston Gifford, Charles A. Terry, and C. P. Steinmetz.

The Associates elected at the Board of Directors' meeting in the afternoon were as follows:

ALEXANDER, JEFFERSON LEAVITT, Superintendent of Water Power, St. Croix Falls Minnesota Improvement Co., St. Croix Falls, Wis.

ALLISON, PHILIP LIVINGSTON, Assistant to Works Engineer, Canadian General Electric Co., Ltd., Peterborough, Ont.

ANGUS, DONALD JAMES, Michigan Agricultural College, East Lansing, Mich.

ARMSTRONG, FRANK WALTER, Electrician, Las Dos Estrallas Minera Cia., El Oro, Mexico

ARNOTT, ROBERT FLEMING, Consulting Engineer, 95 Liberty St., New York City; res., 247 N. Mountain Ave., Montclair, N. J.

BALLARD, WALTER PHILIP, Chief Electrician, Visalia Electric Railroad Co., Exeter, Cal.

BARKER, CECIL JOHN, Chief Electrician, Isthmian Canal Commission, Porto Bello, Canal Zone.

BLAKEMAN, SUTHERLAND RALPH, Student, Purdue University, Lafayette, Ind.; res., Canton, Miss.

BLUNDIN, LEON CLINTON, Electrical Engineer, 40 South 16th St.; res., 1591 N. 52nd St., Philadelphia, Pa.

BODLER, OSCAR WILLIAM, Electrical Engineer, Eastman Kodak Co., Kodak Park Works, Rochester, N. Y.

BOSARD, BURDETTE VICTOR, Superintendent of Construction, Evansville Gas & Elec. Lt. Co.; Evansville, Ind.

BOUGHTON, JUDSON HARTWELL, Secretary & Treasurer, National Light & Improvement Co., St. Louis, Mo.

BRADEN, NORMAN SHORT, Sales Manager, Canadian Westinghouse Co., Ltd., Hamilton, Ont.

BROWN, WILLIAM T., JR., Electrical Engineer, Philadelphia Electrical Bureau, 618 City Hall, Philadelphia, Pa.

BROWNE, RALPH COWAN, Inventor, Browne Apparatus Co.; res., 27 Central Street, Salem, Mass.

BULLARD, BENJAMIN, Operator, United Missouri River Power Co., Helena; res., Canyon Ferry, Mont.

BURNS, JAMES FREDERICK, 442 State State Street, Schenectady, N. Y.

CARLIN, WILLIAM A., Senior Engineer, U. S. Soldiers' Home; res., 112 Seventh Street, N. E., Washington, D. C.

CARROLL, RANDOLPH STRIKER, Tester, Transmission Dept., Portland Railway Light & Power Co.,Portland, Ore.

CASSITY, LEONARD H., President and Manager, Decatur Electric Machine & Equipment Co., Decatur, Ill.

CHILSON, JAMES HOUSTON, Supervising Electrical Engineer, The Arizona Copper Co., Ltd., Clifton, Arizona.

CLOUD, FREDERICK WILLS, Engineer, Westinghouse Electric & Mfg. Co., Pittsburg; res., 724 Wallace Ave., Wilkinsburg, Pa.

COFFIN, S. MARION, Master Mechanic, Mobile Light & R.R. Co., Mobile, Ala.

COLLIS, ALFRED GEORGE, Representative of Engineering Department, Ferranti Limited, Hollinwood, Lancashire, England.

CONVILL, JAMES O., Student, University of Utah; res., University Apartments, Salt Lake City, Utah.

CORBIN, MATTHEW MAURY, General Electric Co., Philadelphia; res., 274 High St., Germantown, Pa.

CORNELIUS, MARTIN, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg; res., 908 Ramsey St., Wilkinsburg, Pa.

DALES, JAMES STUART, JR., Manager, Franklin Water, Light & Power Co., Franklin, Ind.

DANSIE, FRANK, Chief Clerk, Mexican Light & Power Co., Ltd., Necaxa, Puebla, Mexico.

DAVIS, EDWIN RANSOME, Electrical Engineer, Pacific Light & Power Co., Los Angeles, Cal.

DECKER, GEORGE EDGAR, 643 West 16th Street, Los Angeles, Cal.

DERGE, FERDINAND JULIUS, Cadel Engineer, Denver Gas & Electric Co.; res., 1727 Grant Street, Denver, Colorado.

DILLARD, JAMES B., Captain, Ordnance Department, United States Army, War Department, Washington, D. C.

DOLL, CLARENCE EMIL, Treasurer, Fullerton Case Co.; res., 323 West 100th Street, New York, N. Y.

DURKEE, BENTON STORRS, Chief Operator, Postal Telegraph-Cable Co., res., 395 Brazee St., Portland, Ore.

DYCHE, HOWARD EDWARD, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg; res., 818 South Ave., Wilkinsburg, Pa.

Elsom, Thomas Henry, City Plant Chief, The Pacific Tel. & Tel. Co., Spokane, Wash.

Emerson, Ralph W., Engineering Assistant, The Municipal Traction Co.; res., 8212 Carnegie Ave., Cleveland, Ohio.

Eskew, Walter Elliott, Supt. of Power Plant, Pacific Gas & Electric Co., Electra, Cal.

Fales, Henry Marshall, Jr., Plant Department, American Tel. & Tel. Co., 22 Thames St., New York, N. Y.

Ferris, James W., Ferris Brothers, Union City, Ind.

Fisher, Harry Herbert, Chief Engineer, South Park Commissioners; res., 436 East 54th Place, Chicago, Ill.

Fullerton, Darwin Phelps, Division Superintendent, The Pacific Tel. & Tel. Co., San Francisco; res., San Mateo, Cal.

Ganong, Walter Kierstead, Professor of Electrical Engineering, The University of Maine, Orono, Maine.

Gawtry, Louis Brown, Director, New York Edison Company, 4 Irving Place, New York, N. Y.

Girdler, Tom Mercer, General Superintendent, Atlanta Steel Co.; res., 848 West Peachtree St., Atlanta, Ga.

Glauber, Moses M., Clerk, The Ameri-Telephone & Telegraph Co.; res., 1500 East Grand Ave., St. Louis, Mo.

Goldman, Jacob E., Electrical Contractor, 639 South Street, Philadelphia, Pa.

Gooding, Harry Carter, Inspector, Toronto Electric Lt. Co.; res., 180 Beverly St., Toronto, Ont.

Grant, Lawford Stanley Foster, Manager, British Insulated & Helsby Cables, Ltd., Power Bldg., Montreal, Canada.

Griffiths, Morgan Reginald, Manager, Electrical Dept., The Canadian H. W. Johns-Manville Co., 85 Wellington St. W., Toronto, Canada.

Guckel, Charles Henry, Electrical Engineer, 415 Halsey Street, Brooklyn, N. Y.

Harding, William A., Erecting Foreman, United States Reclamation Service; res., 2128 Reservoir St., Los Angeles, Cal.

Haring, James Yost, Superintendent Electrical Department, Sioux City Gas & Electric Co., Sioux City, Iowa.

Hately, James Joseph Charles, Electrical Engineer, American Telephone & Telegraph Co., 803 Star Building, St. Louis, Mo.

Hennecke, Earle Valentine, Salesman, The Tungstolier Company, Cleveland; res., Bucyrus, Ohio.

Hess, Frederick Mortimer, Owner and Manager, Inyo Telephone Co., Bishop, Cal.

Holcomb, Anson Munson, Laboratory Instructor, Sibley College, Cornell Univ.; res., 103 Quarry Street, Ithaca, N. Y.

Hooker, Duncan Collens, Assistant to Electrical Engineer, The Johns-Pratt Co.; Hartford, res., Farmington, Conn.

Houghton, Hugh F., Chief Electrician, Ferro Machine & Foundry Co.; res., Wheeler Apartments, Cleveland, Ohio

Hume, Fred, Electrical Engineer, Chicago, Lake Shore & South Bend Ry., Michigan City, Ind.

Hutton, Charles Hyde, The Dominion Power & Transmission Co., Hamilton, Ontario.

Israel, Joseph David, District Manager, Philadelphia Electric Co.; res., 117 So. 43rd St., Philadelphia, Pa.

Johnson, Carl Edward, Superintendent and Engineer, W. S. Electrical Mfg. Co., 214 S. San Pedro St., Los Angeles.

Johnson, Harry Sackett, President, The F. P. Little Electrical Co., Buffalo; res., East Aurora, N. Y.

Kammerer, Charles Frederick, Electrical Draftsman, The United Railways and Electric Co., of Baltimore, Md.

Kennedy, David Ramsay, Engineer in Charge, Vancouver Power Co., Lake Buntzen, B. C.

Kenyon, Ransom Schofield, Electrician, New Orleans Ry. & Lt. Co.; res., 6325 Patton St., New Orleans, La.

King, William Francis, System Operator, The New York Edison Co.; res., 305 West 126th St., New York City.

Kingsbury, Nathanial Lee, Foreman, The Home Telephone Co.; res., 294 Fargo St., Portland, Ore.

Kirkland, Hugh A., Superintendent of Equipment, Home Telephone Co.; res., 818 Multnomah St., Portland, Ore.

Kylie, Harry Raymond, Maintenance, New England Tel. & Tel. Co., 164 High St., Boston; res., 24 Cordis Street, Charlestown, Mass.

Leonard, Alton William, Manager, The Minneapolis Gen. Elec. Co., 15 So. Fifth St., Minneapolis, Minn.

Little, Arlington Pearl, Assistant Professor of Electrical Engineering, Syracuse University, Syracuse, N. Y.

Loder, Frank Floyd, Meter Man & Foreman of Line Construction, Rogue River Electric Co., Medford, Ore.

Long, Jacob Michael, Operator in Charge, Pacific Light & Power Co.; res., 2821 No. Griffin Ave., Los Angeles, Cal.

Luther, Benjamin Sisson, Superintendent, The Chase-Shawmut Co., Newburyport, Mass.

Manson, George Kimball, Engineer, The New England Tel. & Tel. Co., 164 High Street, Boston, Mass.

Marshall, Stewart McCulloch, Asst. Chief Engineer, Cambria Steel Co.; res., 120 Tioga Street, Johnstown, Pa.

Martin, Frank Percy, Electrician, Sheriff Street Market & Storage Co.; res., 2215 East 103rd St., Cleveland, Ohio.

Mathews, Ralph Berkeley, Inspecting Engineer, Board of Fire Underwriters of the Pacific, 461 Colman Bldg., Seattle, Wash.

Maughan, Allan, Operator, Seattle Electric Co.; res., 1418 7th Avenue, Seattle, Wash.

Maupin, Samuel Toler, Superintendent, Electric Light & Water Works, Madison, Georgia.

McAfee, Walter Clark, Superintendent, Electrical Dept., Atlanta Steel Co., Atlanta, Ga.

McDougall, Douglas Howard, Assistant Comptroller, The Toronto Power Co.; res., 254 McPherson Ave., Toronto, Ont.

McLaughlin, James F., Chief, Philadelphia Electrical Bureau, City Hall; res., 1742 Diamond St., Philadelphia, Pa.

Middleton, Washington Irving, Electrical Engineer, The Simplex Electrical Co., Boston; res., 50 Highland Ave., Cambridge, Mass.

Miller, Charles William, Construction Foreman, Rochester Railway & Light Co., Rochester, N. Y.

Minns, Raymond Howard, Student Apprentice, Westinghouse Electric & Mfg. Co., Pittsburg; res., 815 Franklin Ave., Wilkinsburg, Pa.

Mitchell, George W., Switchboard Manager, Home Tel. & Tel. Co., East 11th & Morrison Sts., Portland, Ore.

Mitchell, Percival Howard, Consulting Engineer, 1005 Traders Bank Bldg., Toronto, Ontario.

Mitchell, Ralph Molyneux, Captain, Coast Artillery Corps, U. S. A., Fort Monroe, Va.

Mock, James Curtin, Electrical Engineer, Detroit River Tunnel Co.; res., 147 Virginia Ave., Detroit, Mich.

Monk, Holman W., Expert Electrician, The Carolina Power & Light Co., Raleigh, N. C.

Morgan, Don Dewitt, Chief Operator, Pacific Light & Power Co., 254 S. Los Angeles St., Los Angeles, Cal.

Morgan, Robert Churchman, Chief Engineer, Francis Brothers & Jellett, Inc., Broad & Wallace Sts., Philadelphia, Pa.

Nash, Franklin Marian, Station Superintendent, The Telluride Power Co.; res., Pleasant Grove, Utah.

Neu, S. Sidney, Publicity Engineer, Crocker-Wheeler Co., Ampere; res., East Orange, N. J.

Newton, Otis Sherman, Chief Engineer, Mansfield Ry. Lt. & Pr. Co.; res., 184 W. 5th St., Mansfield, Ohio.

Nicholls, Henry Grayburn, Assistant General Manager, Canadian General Electric Co.; res., 422 Sherbourne St., Toronto, Ontario.

Nock, Geoffrey Proctor, Clerk, The Pacific Telephone & Telegraph Co., Portland, Oregon.

Norman, Reuben Charles, Operator, La Crosse Water Power Co., Hatfield; res., Merrielan, Wis.

Nye, Arthur Wickes, Associate Professor of Electrical Engineering, University of Southern California, Los Angeles, Cal.

Orr, Charles W., Construction Work, International Smelting & Refining Co., Tooele, Utah.

Owens, Charles C., Selling Engineer Westinghouse Electric & Mfg. Co., New York City; res., 624 E. 17th St., Brooklyn, N. Y.

Parrish, Junior, Electrical Engineer, United States Civil Service, Fort Leavenworth, Kansas.

Pearson, Benjamin Franklin, Superintendent, Edison Electric Co., Los Angeles, Cal.

Peirce, Herbert Benjamin, Student, Harvard University; res., 8 Holworthy Hall, Cambridge, Mass.

Perry, William John, Chief Wireman, The Canadian Iron Corporation Ltd.; res., 1301 Ford St., Fort William, Ont.

Phelps, Howard Sanford, Superintendent of Power, The Crystal River Marble Co., Marble, Colo.

Pierce, Milton Stanley, District Manager, The Northern Electric & Mfg. Co., Ltd., 62 Front St., West, Toronto, Ont.

Pouch, Oscar Garfield, President Oswald Electric & Engineering Co., New York City; res., 15 Phillips Pl., Yonkers, N. Y.

Procter, John Robert, Captain, Coast Artillery Corps, U. S. A., Fort Monroe, Virginia.

Reimer, Adolph, Jr., Foreman, Edison Elec. Ill. Co. of Brooklyn; res., 496 Putnam Ave., Brooklyn, N. Y.

Rhodes, Thomas A., Jr., Draftsman, N. Y. C. & H. R. R.R.; res., 455 West 21st St., New York, N. Y.

Riedell, Paul William, Electrical Draftsman, General Electric Co.; res., 1011 Duane Ave., Schenectady, N. Y.

Rodgers, James Franklin, Sales Engineer, Allis-Chalmers Co.; res., 600 N. St. Clair St., Pittsburg, Pa.

Rutledge, George Edward, Construction Foreman, General Electric Co.; res., 912 Noe Street, San Francisco, Cal.

Schaefer, Carl Julius Herrman, Asst. Chief Operator, Cauvery Power Scheme, Champion Reefs, Kolar Gold Fields, Mysore Province, India.

Schwarz, Paul Gerhard, Supt. & Erecting Engineer, New Bremen Municipal Lt. & Water Plant, New Bremen, Ohio.

Searing, Emery De Forest, Draftsman, Portland Railway Light & Power Co.; res., 1252 Hawthorne, Ave., Portland, Ore.

Searle, Robert Meredith, Vice-president, Rochester Railway & Light Co., 30 Clinton Ave., No., Rochester, N. Y.

Sheely, James Henry, Engineering Assistant, New York Telephone Co., New York City; res., 736 St. John's Place, Brooklyn, N. Y.

Shoemaker, Richard Samuel, Electrical Superintendent, Pittsburg, Steel Co., Monessen, Pa.

Simon, Emil Jacob, Student, Columbia University; res., 527 West 121st Street, New York, N. Y.

Skelley, Frank Vernon, Electrical Engineer, Western Electric Co., Hawthorne; res., Morton Park, Ill.

Somers, James, Engineer, Harwood Electric Light & Power Co., Harwood Mines, Pa.

Stahl, Axel J., Engineer, Forenade Elektriska A. B., Uplandsgatan 58, Stockholm, Sweden.

Steele, William Irving, Assistant Electrical Engineer, The Federal Lead Co., Farmington, Missouri.

Stephenson, Ralph, General Foreman, Iowa Telephone Co., Des Moines, Iowa.

Stevenson, Robert Elmer, Instructor in Electrical Engineering, Polytechnic Institute, Oakland; res., 1628 Woolsey St., Berkeley, Cal.

Stroh, Henry Nicholas, Jr., Northern Westchester Lighting Co., Ossining, N. Y.

Sykes, Wilfred, Westinghouse Electric & Mfg. Co.; res., 742 North Highland Ave., Pittsburg, Pa.

Thompson, George William, General Superintendent, Westmount Light & Power Dept., Westmount; res., 14 Tupper St., Montreal, Canada.

Thompson, James Cox, Chief Electrician, United Electric & Valley Traction Co., Lemoyne, Pa.

Thornton, Edwin Burdette, Operator, La Crosse Water Power Co., La Crosse; res., Hatfield, Wis.

Trammell, William Harrison, General Superintendent, Belton Power Co., Belton, S. C.

Wagner, Robert Edward, Superintendent of Testing Dept., Canadian General Electric Co., Peterboro, Ontario, Can.

Waller, Benjamin, Engineer, The Northwestern Telephone Exchange Co., Minneapolis, Minn.

Warren, Chester Howard, Assistant, Pacific Gas & Electric Co., San Francisco; res., 2430 Channing Way, Berkeley, Cal.

Waugh, Lester Rogers, Inspector of Electric Construction, Edison Electric Illuminating Co., Brooklyn, N. Y.

Weber, Eugene, Draftsman, with H. S. Crocker, 434 Empire Building, Denver, Colorado.

Weber, Fred Dale, Electrical Inspector, Board of Fire Underwriters of Pacific, 559 Sherlock Building, Portland, Ore.

West, Oscar Haines, Division Electrician, Indiana Union Traction Co.; res., 514 Delaware St., Anderson, Ind.

Wharton, James Burton, General Agent, Wilkes Barre Gas & Electric Co.; res., 25 No. Main St., Wilkes-Barre, Pa.

Wilkinson, Charles Decatur, District Manager, Western Electric Co., 114 3rd St., N., Minneapolis, Minn.

Wilson, Chas. Westley, Erecting Engineer, Westinghouse Machine Co., E. Pittsburg, Pa.; res., 557 Alcatraz Ave., Oakland, Cal.

Wilson, George Alexander, Electrician, Joseph S. Burr & Co., 310 Chestnut St.; res., 2137 Catharine St., Philadelphia, Pa.

Woodbury, Ezra Ernest, Standard Underground Cable Co., Pittsburg; res., 14 Emerson Ave., Crafton, Pa.

Woodill, H. B., Manager, Woodill & Hulse Electric Co.; res., 1026 Lake St., Los Angeles, Cal.

Wurth, William, Division Engineer of Power Chicago City Railway Co., 1644 First Nat. Bank Bldg., Chicago, Ill.

Total 151.

The two Associates transferred to the grade of Member were:

Charles George Adsit, Consulting Electrical and Mechanical Engineer, Magdalena, Sonora, Mexico.

Edmund Munroe Sawtelle, Consulting Engineer, Temple Court, New York City.

Applications for Election

Applications have been received by the secretary from the following candidates for election to the Institute as Associates; these applications will be considered by the Board of Directors at a future meeting.

Any Member or Associate objecting to the election of any of these candidates should so inform the secretary before June 20, 1909.

8649	Clarke, R. B., Toronto, Ont.
8650	Davis, W. R., New York, N. Y.
8651	Ehrenborg, G. B., Seattle, Wash.
8652	Hickox, N. B., Rome, Ga.
8653	Kelterborn, A. G., New York, N.Y
8654	Bott, T. W., Globe, Ariz.
8655	Coriell, L. D., Baltimore, Md.
8656	Hess, S. H., San Francisco, Cal.
8657	Kleine, W. O., Cincinnati, Ohio.

8658 Lozier, I. N., Sandersville, Ga.
8659 Matthews, C. L., St. Louis, Mo.
8660 Millener, F. H., Omaha, Neb.
8661 Parker, T. H., San Francisco, Cal.
8662 Shearer, David R., Nashville, Tenn.
8663 Adams, R. F. L., Boston, Mass.
8664 Clark, H. H., Pittsburg, Pa.
8665 Crowley, V. J., Oroville, Cal.
8666 Dunn, D. P., Vancouver, B. C.
8667 Fox, J. J., Newark, N. J.
8668 Green, F. C., Pittsfield, Mass.
8669 Kaarsberg, L. C. H., Vallejo, Cal.
8670 Dwyer, R. C., Wilkinsburg, Pa.
8671 Kibbe, G. E., Portland, Ore.
8672 Ryan, R. R., Ann Arbor, Mich.
8673 Wessel, J. F., Lynchburg, Va.
8674 Hollinger, Harry, Altoona, Pa.
8675 Baker, L. E., Spokane, Wash.
8676 Barns, B. L., Ann Arbor, Mich.
8677 Edwards, E. J., Roxbury, Mass.
8678 Porter, W. J. D. A., Utica, N. Y.
8679 Chandler, C. De F., Ft. Omaha, Neb.
8680 Pragst, E. W., Schenectady, N. Y.
8681 Unger, M., Pittsfield, Mass.
8682 Marsh, L. J., Lynn, Mass.
8683 Woodville, A. W., Seattle, Wash.
8684 Buchanan, M. W., Washington, D.C.
8685 Hull, A. H. Toronto, Ont.
8686 Sanford, A. L., Boston, Mass.
8687 Boring, G. A., Seattle, Wash.
8688 Hardy, William, Fort Mills, P. I.
8689 Hohn, Emil, New York, N. Y.
8690 Kauffman, Roy, Seattle, Wash.
8691 McCosker, Chas. S., Mobile, Ala.
8692 Schwendener, H. G., Battle Creek, Mich.
8693 Blathy, O. T., Budapest, Hungary
8694 Jacobs, H. M., Schenectady, N. Y.
8695 Phelan, P. L., New York, N. Y.
8696 Roth, Charles, Chicago, Ill.
8697 Shepard, W. M., San Francisco, Cal.
8698 Fisher, H. A., Chicago, Ill.
8699 Levings, S. D., Chicago, Ill.
8700 Balling, G. A., Chicago, Ill.
8701 Drennen, C. E., Denver, Colo.
8702 Freygang, Paul J., Chicago, Ill.
8703 Nelson, Fred C., St. Paul, Minn.
8704 Stephens, F. S., Madras, India.
8705 Filer, C. F., Miami, Florida.
8706 Miller, L. D., Boston, Mass.
8707 Sewell, H. R., Galveston, Texas.
8708 Theis, A. J., San Francisco, Cal.
8709 Chubb, L. W., Pittsburg, Pa.
8710 Doud, Willard, Chicago, Ill.
8711 Fritch, L. C., Chicago, Ill.
8712 Hermann, H., Chicago, Ill.
8713 Harold, W. H., Clay Center, Kans.
8714 Himmelsbach, J. W., Pittsfield, Mass
8715 Moore, F. H., Indianapolis, Ind.
8716 Darrah, W. A., Worcester, Mass.
8717 Mahoney, F. W., Taunton, Mass.
8718 Merrill, F. W., Chicago, Ill.
8719 De France, M. E., Mobile, Ala.
8720 Heather, A. G. F., Transvaal, S. A.
8721 Marshall, J. C., Laredo, Texas.
8722 Munson, A. H., Toronto, Ont.
8723 Chaphe, J. L., Cazenovia, N. Y.
8724 Demke, A. H., Portland, Ore.
8725 Kenly, E. M., Yakima, Wash.
8726 Forgee, F. A., New York City.
8727 Morrison, J. W., Jr., Rochester, N. Y.

Total, 79.

Applications for Transfer

The following Associates were recommended for transfer by the Board of Examiners May 18, 1909. Any objection to these transfers should be filed at once with the secretary.

William Newton Ryerson, General Manager, Great Northern Power Co., Duluth, Minn.

John Castlereagh Parker, Mechanical and Electrical Engineer, Rochester N.Y.

Barzillai Gardner Worth, Electrical Engineer, Plainfield, N. J.

Walter J. Warder, Jr., Electrical Engineer, Roth Bros. & Company, Chicago, Ill.

Dudley Farrand, General Manager, E. E. Dep't., Public Service Corporation of New Jersey, Newark, N. J.

William Leslie Hooper, Professor of Electrical Engineering, Tuft's College, Mass.

H. A. Holdrege, General Manager, Omaha Electric Light & Power Company, Omaha, Neb.

The Satellite Systems of Primary or Pioneer Inventions

The appearance of a radically novel and really great invention which pioneers a new industry or which effects remarkable results in the service of man, is invariably and inevitably followed, when brought into commerical use, by a host of more or less direct satellite improvements, real or fancied, and supplemental or accessory inventions, to make such use more effective, convenient and profitable. This statement expresses so general a truth that the magnitude of the environment of subsidiary invention thus stimulated, ultimately affords, in some degree at least, a rough measure of the consequence, merit, and usefulness of the primary invention or discovery so supported.

While experience has demonstrated the correctness of this proposition in many directions of progress based on invention, particularly in the domain of the electrical science, its most striking illustration is probably to be found in the history of the telephonic art, and in the improvements, or supposed improvements, in telephones and telephonic apparatus and lines which have surrounded the original invention and which have contributed materially to the revolution in methods of transacting business that has been brought about by the ubiquity and general employment of the telephone.

Before the year 1876 there were no speaking telephones anywhere. At the close of 1908, the number of telephone exchange users' stations connected with the Bell or American Telephone and Telegraph Company's system was 4,364,629.

The fundamental telephone patent of Alexander Graham Bell was granted March 7, 1876, and in the summer of the same year the speaking telephone was shown and operated at the Centennial Exhibition and was introduced to the public. This patent covered the art of transmitting speech electrically over a wire, together with suitable instruments by means of which that art might be practiced.

During the year 1876 no patents for inventions relating to telephony other than this pioneer patent of Bell were granted. During the following year, 1877, three patents were granted for telephone inventions, one of which was issued to Bell himself for improvements which he had made in the construction of his magneto telephones; and in 1878 there were granted in the United States 23 patents for telephones and 13 for accessory apparatus. The first line ever built for telephonic communication was established in the spring of 1877.

As originally introduced, instruments identical in principle, and form to the present receiver were employed both to transmit and receive. This type of instrument was from the first an excellent receiver; no one has ever been able to make any substantial or material improvement in it for the exercise of the receiving function. It is practically the same now as when originally brought out by Bell 33 years ago. But as a transmitter it was not highly effective, and the earliest group of satellite inventions looked to the production of a more powerful transmitting instrument. Such an instrument had indeed been thought of by the inventor of the telephone, and the direction in which it might be obtained was suggested in his patent. The highly efficient standard transmitter of the present time is the outcome of the labors of many investigators, and comprises at least five different inventions of some importance, and also several of minor character.

While many improvements in actual speech transmission, or directly relating to the speaking telephone, have been made, the production of accessory and auxiliary apparatus, and to its best known and principal utilization, the telephone exchange, has offered a much

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*Summary of a paper read by Mr. T. D. Lockwood at a meeting of the Pittsfield Section, May 7, 1909.

wider field for the exercise of inventive skill; and a multitude of satellite appliances in this branch of telephony have been devised and patented. These comprise call bells, switchboards, devices for protecting telephone apparatus and lines from the destructive effects of heavy currents and discharges, aerial and underground cables, projects for telephone exchange work, the suppression of inductive disturbance, and many other collateral subjects. In all these branches of development many improvements have been made and many inventions patented.

The switchboard, now and for many years past used in large central stations, was in its inception an improvement of very great consequence, and a large number of inventions are or have been concerned in it, as may be inferred from the fact that up to the end of 1908 over 1200 United States patents for such switchboards and for supposed improvements relating to them have been granted.

Within the 32 years that the telephone has been in use by the public, that is, from 1876 to 1908, there have been issued by the United States Patent Office 1431 patents for improvements and assumed improvements on the telephone itself and in the art of electrically transmitting speech, and 7098 patents for accessory appliances, making a total of 8529 satellite patents; while of foreign patents for like inventions there have been granted during the same period an aggregate of approximately as many more. All of these, both domestic and foreign, are directly attributable to the original and primary invention of the electrical speaking telephone.

Electrical Expert (Wireless Telegraphy and Telephony). Navy Department, June 9, 1909

The United States Civil Service Commission announces an examination on June 9, 1909, to secure eligibles from which to make certification to fill a vacancy in the position of electrical expert (wireless telegraphy), in the Bureau of Equipment, Navy Department, at a salary of $3,000 per annum, and vacancies requiring similar qualifications as they may occur.

Competitors will not be assembled for any of the tests.

The duties of the appointee to this position will be as follows: To have charge of the laboratory tests of all instruments and apparatus pertaining to wireless telegraphy; the standardization of circuits and instruments used in wireless; the development of special apparatus and methods of wireless signalling suited to special conditions, and of new forms of sending and receiving circuits; to inspect the various wireless stations and to make the necessary measurements of their electrical constants; to carry on quantitative experimentation and original investigation in wireless telegraphy, and, in general, to carry out such work as may be necessary for the development of the science.

The examination will consist of the subjects mentioned below, weighted as indicated:

Subjects	*Weights*
1. General and technical educational training	10
2. Technical experience	20
3. Special experience in wireless telegraphy and telephony	40
4. Original research and experiments in electrical science with special application to wireless telegraphy and telephony	30
Total	100

Competitors who fail to receive a rating of at least 70 per cent in the third subject will not be eligible for appointment.

Age limit, 21 years or over, on the date of the examination.

This examination is open to all citizens of the United States who comply with the requirements.

This announcement contains all information which is communicated to applicants regarding the scope of the examination, the vacancy or vacancies to be filled, and the qualifications required, Applicants should at once apply to the United States Civil Service Commission, Washington, D. C., for application Form 304 and special form. No application will be accepted unless properly executed and filed, with the material required, with the Commission at Washington prior to the hour of closing business on June 9, 1909. In applying for this examination the exact title as given at the head of this announcement should be used in the application.

Issued May 11, 1909.

Sections and Branches

ARMOUR INSTITUTE OF TECHNOLOGY BRANCH

At the meeting of the Branch held on April 22, Mr. G. E. Marsh delivered a lecture on the " Pinch Interrupter ", a name used to designate the so-called electrolytic type of interrupter by reason of the phenomenon on which the apparatus operates. The general nature of the pinch phenomenon, which may be defined as the contraction in the cross-sectional area of a liquid conductor when the current passing through it is sufficiently large, was described in detail. The mathematical relations connecting the various factors and several equations were shown by means of their graphs, which indicated the involved relationships. The active pressure directed along the axis of a liquid conductor in consequence of this pinch effect was exhibited by means of a modified interrupter. The latter part of the paper dealt with the constructional features of the apparatus. The dependency of the frequency on the size of aperture, and the current density and inductance of the circuit were pointed out, as well as the high capacity effect displayed by the apparatus when operating under certain conditions. The interrupter was of a construction that involved several new and marked features which contribute to its successful operation over long periods. The lecture was followed by a general discussion.

" The Permutator " was the subject of a paper read by Mr. F. C. Zanzig before the Branch on May 6. The introduction to the paper consisted of an analysis of the definition of a permutator. With this in mind the speaker drew attention to the failures of the early inventors of this machine because of their lack of distinction between the permutator and the synchronous converter. Most of the evening was devoted to the theory and operation of the Rogue-Faget type. Curves showing the effects produced by various loads, brush-leads, impressed voltages and frequencies were shown, besides the vector diagram obtained from tests made on a 9-kw., two-phase machine. The windings necessary to bring about inductive balance and sparkless commutation for all loads were explained in detail. The speaker showed that compared with the converter, the permutator was in every way its equal, or better, except in respect to the wide variations of power-factor obtainable with a converter. He also pointed out that its small weight and floor space, absence of transformers and auxiliary switching apparatus, simple starting action and operation, and suitability for any voltage, were some of the many points of advantage the permutator possesses over the converter.

In the report of the meeting of the Branch held on March 19, the paper on " Industrial Engineering " was prepared and presented by Mr. F. A. Lindberg, and not by Messrs. Lindberg and Brill as the wording of the report would indicate.

ATLANTA SECTION

A meeting of the Atlanta Section was held on April 6, 1909. At the suggestion of Mr. A. M. Schoen it was decided to continue the meetings throughout the summer, with a view to keeping up the interest in Institute work. Arrangements were made for papers for the next two meetings. Mr. Collier promised a paper on " Load

Factor" for the June meeting, and Mr. Bonyun one on "Mercury Rectifiers" for the July meeting. Mr. Yundt read an interesting original paper on "Wireless Telephones." Beginning with the earliest methods of signaling with light, Mr. Yundt covered the whole field of wireless signaling down to the present methods of wireless telephony. As the paper was of considerable length, and Mr. Yundt's time was limited, the discussion of the paper will take place at the next meeting.

BALTIMORE SECTION

The regular monthly meeting of the Baltimore Section was held on Thursday evening, May 13. A paper entitled "Demonstrations of Lightning Phenomena" was presented by Mr. E. E. F. Creighton, of Schenectady, N. Y. The speaker described with the aid of lantern slides and experiments the nature of lightning phenomena. He described the aluminum electrolytic lightning-arrester and explained its improved continuous capacity over that of the multigap arrester. The different classes of service to which these two types of arresters are best adapted were also described. The experimental demonstrations were of great value in illustrating the principles laid down by the speaker. Forty members were present.

BOSTON SECTION

The regular monthly meeting of the Boston Section was held on Wednesday evening, April 21, 1909, in the auditorium of the Edison Building. Professor D. C. Jackson, vice-chairman, presided. Captain Clifton C. Carter presented a paper on "Coast Defence." There was an attendance of about 150.

CHICAGO SECTION

At the meeting of the Chicago Section held on April 30, Mr. B. R. Shover, of the Indiana Steel Company, gave an illustrated talk on the electrical equipment of the Gary steel plant. About 150 members and other engineers were present.

On April 24 the members of the Section and the Western Society of Engineers availed themselves of an invitation to visit the Indiana Steel Company's plant at Gary, Indiana. Between 400 and 500 engineers from the two organizations made the trip and inspected the plant.

UNIVERSITY OF CINCINNATI BRANCH

The University of Cincinnati Branch held a meeting on April 20, 1909. The regular order of business was suspended in order to allow the speaker of the afternoon to have the entire time. Mr. George Walker, of the Cooper-Hewitt Electric Company, gave a talk on "Mercury Vapor Lamps." He displayed a number of different types of lamps, showing their relative lighting efficiency and color effect. He also told how they were manufactured and of their uses in the commercial world.

CLEVELAND SECTION

The regular meeting of the Cleveland Section was held in the Case School of Applied Science, on April 19, 1909, at 8 p.m. Mr. P. F. Bauder presented a paper on "Quality of Light." He treated the subject from a scientific standpoint, but made it most interesting. In view of the rapid changes in illuminating standards and sources, the subject was timely, and brought out considerable discussion on the quality and characteristics of light from the various electric illuminants.

ITHACA SECTION

The most successful meeting in the history of the Ithaca Section was held on April 23, 1909. Four hundred members and visitors were present. Mr. Frank J. Sprague, of New York City, had been invited to address the Section. Mr. Sprague's subject was "Some Comments on the Electrification of Steam Railways." An abstract of the paper will probably be printed in an early issue of the Institute PROCEEDINGS.

UNIVERSITY OF KANSAS BRANCH

This Branch held a meeting on April 14. There was a total attendance of 26. Mr. T. P. Pinckard, of the Kansas City office of the Westinghouse Electric & Manufacturing Company, gave a talk on " The Work of a Salesman for a Large Electrical Manufacturing Company." A number of questions were asked Mr. Pinckard at the conclusion of his talk.

The second April meeting was held on April 28, with Mr. Ray Jones presiding, and a total attendance of 15. Mr. J. F. Wilson gave an account of his experiences as an electrical engineer on power work in the states of Washington and Oregon.

LEHIGH UNIVERSITY BRANCH

The regular April meeting of this Branch was held in the physical laboratory on April 20, Mr. A. S. Garrison presiding. After the transaction of some routine business Professor Franklin gave a paper on the " Gyroscope." He first showed a number of lantern-slides illustrating the theory of the gyroscopic action. He then showed how this action was made apparent in automobiles, due to the fly-wheels, and also in many practical devices.

At the conclusion of Professor Franklin's remarks, Professor William Esty presented a paper on " Submarine Cables and Telegraphy." The subject aroused much interest. The meeting was followed by a lunch. There was an attendance of 60.

LOS ANGELES SECTION

The Los Angeles Section held a special meeting on March 1, 1909, with Mr. J. E. MacDonald presiding, and an attendance of 54. After an abstract of the Institute paper on " Log of the New Haven Electrification " had been presented, a lecture on " Commercial Insulation " was delivered by Mr. F. H. Dimock.

The regular monthly meeting was held on March 16, which was presided over by Mr. C. W. Koiner. Fifty-five members were present. A paper was presented by Mr. C. A. Copeland, entitled "Transformer Kinks and Wrinkles.

The next regular meeting was held on April 20, with Mr. C. W. Koiner in the chair, and an attendance of 32. Mr. W. B. Gump presented a paper entitled " Some Practical Considerations Concerning the Choice of Prime Movers." Following this the Institute paper on " Prime Movers," by Charles P. Steinmetz, was abstracted and discussed.

MADISON SECTION

The April meeting of the Madison Section was held in the auditorium of the City Library on the evening of April 28. There were 40 members and visitors in attendance. The program consisted of an original paper on " The Uses of Electricity on Shipboard", which was presented by Professor C. C. Thomas. The paper was illustrated with numerous lantern-slides showing the equipment both for naval and merchant vessels. At the conclusion of the discussion on the paper, Mr. F. Ellis Johnson gave an abstract of the Institute paper on " Prime Movers."

UNIVERSITY OF MICHIGAN BRANCH

At the meeting of the University of Michigan Branch held on April 28, Mr. L. S. Hill, of the medical department of the university, and an electrical engineering graduate, gave a lecture on "Resuscitation from Apparent Death Due to Electric Shock." He described the physical effects of electric shock, and the effect of variation of electromotive force applied, and currents passing through the body. He explained how death may be caused by electric shock, and described the temporary paralysis often mistaken for death.

On May 5, Mr. L. S. Hill gave a summary of his lecture delivered at the previous meeting, April 28, on "Resuscitation from Apparent Death Due to Electric Shock." There was an attendance of 42 members and visitors at this meeting. Mr. Hill gave a demonstration of the method of resuscitation recommended by him. In the discussion which followed, the different methods used were described, and some experiences and applications given. Those taking part were Professor G. W. Patterson, Messrs. Hall, Baxter, and Barns.

UNIVERSITY OF MISSOURI BRANCH

The University of Missouri Branch held a meeting on May 7, 1909, with an attendance of 20. Mr. H. D. Carpenter presided, and two Institute papers were presented and discussed. The paper on "Condenser Type of Insulation for High-Tension Terminals" was presented by Mr. R. A. Beekman. After the discussion of this paper, Mr. H. L. Andrews presented the paper entitled "High-Tension Transformers and Controlling Apparatus for Outdoor Installation." A general discussion followed.

NEW HAMPSHIRE COLLEGE BRANCH

At a special meeting of this Branch held on May 3, 1909, Frank Davis, M.D., of Boston, Mass., delivered an entertaining lecture to a large audience, on "Some Forms of Electro-Radiations, Their Value as Aids in the Diagnosis and Treatment of Disease." In the course of his remarks, Dr. Davis spoke of the theories which had been advanced to explain the different phenomena in the universe, and stated that the electron theory is gradually being accepted as the explanation of these phenomena. The electron theory rests upon the assumption that all phenomena have the same structural unit—the electron—which is a minute charge of negative electricity, self-centered, and integral. The speaker proceeded to give some applications of this theory and to show how some of them could be illustrated. A hypothetical experiment was assumed where it was supposed that an iron top was impelled to spin at a constantly increasing rate of speed or vibration. Soon a low humming would be heard which would gradually increase in pitch until finally no sound could be distinguished by the human ear; then would come the different stages of heat radiations, then those of light, followed by absolute darkness, then the ultra-violet rays, then the X-rays, and last, the Roentgen rays. Here the speaker took up the application of the X-ray to the healing of various forms of disease. The ultra-violet rays and high-frequency currents were also illustrated by means of a high-frequency machine which Dr. Davis brought to the meeting for the purpose. The program was concluded with a stereoptican exhibition illustrating the value of the X-ray in diagnosis.

The regular monthly meeting was held on May 10. Mr. P. F. Ellsworth gave a lecture on "Wireless Telegraphy. He described in theory and practice the various kinds of sending and receiving apparatus, also the tuned and untuned systems, and went at some length into the theory of the waves which are transmitted through the ether by the sending station, and how they are received at the receiving end. He also described the various coherers which have been used, starting with the first one, the filings coherer, and continuing up to the electrolytic, silicon and pericon coherers now in use. The lecture was illustrated by a complete set of working apparatus.

OHIO UNIVERSITY BRANCH

The Ohio University Branch, which has been inactive for the past year, has reorganized, and is now established on a more substantial basis. The reorganization was effected at a meeting held on April 27, 1909, at which 24 members were present. A new Constitution was adopted, and the following officers were elected to serve throughout the school year of 1909-1910: President, G. A. Arnold; first vice-president, R. V. Gardner; second vice-president, F. R. Garber; third vice-president, R. A. Brown; secretary and treasurer, J. C. Wagner; corresponding secretary, E. C. Williamson.

A second meeting was held on May 11, at which 19 members were present, with Mr. G. A. Arnold in the chair. Mr. R. S. Van Atta read a paper on " The Panama Canal."

Oregon Agricultural College Branch

The second regular March meeting of this Branch was held on Monday, March 15, 1909. The Section papers on " Transmission Practice in the Northwest," and " Pioneer Developments Within the General Electric Company," printed in the March Proceedings, were abstracted by E. V. Hawley. As Mr. Hawley has spent considerable time in Schenectady, he was able to give a fairly accurate account of the magnitude of the works there at the present time.

Professor T. M. Gardner presented abstracts of the Institute papers on " High-Voltage Transformers and Protective Controlling Apparatus for Outdoor Installations ", and " The Industrial Application of the Electric Motor."

The program for the meeting of April 27, consisted of a paper on " Copper Smelting in California," by Mr. S. H. Graf. As California is not generally looked upon as a copper producing state, the statistics presented in regard to the copper industry in the state were a surprise to many of those present. A large collection of specimens of the ore and the copper in its various stages of smelting, also pictures of the plant to which reference was made, were passed among the members. The attendance at the meeting numbered 14.

The first regular May meeting of the Branch was held on the evening of May 3. Mr. W. A. Schoel presented an abstract of the Institute paper on " Notes on the Cost of Power." The Institute paper on " Industrial Application of the Electric Motor ", was also discussed, and the methods of several steel mills were explained. Mr. W. D. Sutton described the use of electric motors in the mills of the Tennessee Coal, Iron & Railway Company. Mr. C. L. Knopf concluded the evening's program with an abstract of the Institute paper on " Fundamental Principles of Industrial Education." Sixteen members were present.

Pennsylvania State College Branch

The Pennsylvania State College Branch has held weekly meetings during the months of January, February, and March, at which the average attendance was about 50. Dr. A. S. McAllister, associate editor of the Electrical World, spent the week of January 11 to 16 lecturing daily to the senior and junior electrical engineers. His lectures embraced the physical side, omitting the mathematical, thus giving the men a very good conception of the inter-relations of the electric circuits. He also lectured before the Branch on Wednesday evening, January 13, on the alternating-current series motor in its latest form. On the evening of January 15 the Branch gave a reception and banquet in honor of Dr. McAllister, which was attended by over 100 members and guests. Dr. Edwin E. Sparks, president of the college, was present.

At the other meetings some of the speakers were : Mr. Thomas Hall, who lectured on "Economy of Modern Steam Engines. Mr. Hall gave data on engine construction which has never been published. Mr. W. M. Kinney gave an illustrated talk on " The Manufacture of Cement." Mr. A. G.

McKee spoke on blast furnaces. Mr. L. E. Young, director of the Missouri School of Mines and Metallurgy, gave an interesting talk on electric power drills.

PHILADELPHIA SECTION

The meeting of the Philadelphia Section held on May 10 was devoted to the general subject of industrial power. Mr. Paul Spencer presided, and 95 members were present. The following papers were presented: " Polyphase Motors," by D. F. Stokes; " Single-Phase Motors ", by Mr. Bryant " Applications of Electricity to Industrial Work ", by W. Devereaux; " Applications of Motors to Shop Practice," by H. A. Hornor; " Domestic Applications of Electricity ", by R. L. Lloyd. These papers were discussed by Messrs. Young, Devereaux, Day, Keith, Geiser, and Stevens.

PITTSBURGH SECTION

The regular monthly meeting of the Pittsburgh Section was held in Carnegie Institute on April 13, 1909, Mr. W. Edgar Reed, chairman, presiding. The meeting was preceded by the usual dinner at the University Club. The subject of the evening was " Repairing High-Tension Lines While in Service ", an original paper by Mr. J. S. Jenks, who was assisted by W. H. Acker, both of the West Penn Railways Company. By means of a large number of lantern-slides, Mr. Jenks showed the system together with the tools which he and his assistants have developed on their 25,000-volt lines in order to avoid the necessity for linemen to come in contact with the line conductors, and how completely equipped poles could be stripped of all wires and cross-arms, and the insulators, cross-arms and conductors replaced without interrupting any circuit. The paper excited lively interest among the engineers present, which included representative men from all the large electrical companies and public service corporations in the territory. The discussion was participated in by Messrs. H. N. Muller, D. E. Burke, W. H. Acker, N. W. Storer, A. J. Glenn, F. F. Espenschied, O. M. Jorstad, H. A. Calderwood, Graham Bright, R. A. L. Snyder, and Bertrand P. Rowe. One hundred and twenty-five members were present at the meeting.

The May meeting of the Section was held in the Carnegie Institute on May 11. Chairman W. Edgar Reed presided. Mr. C. E. Stephens presented a paper on " Street Lighting." The discussion on the paper was opened by Mr. F. C. Sargent, of Haverhill, Mass., who gave considerable data regarding various systems of street lighting in use in New England. He was followed by Mr. Charles F. Scott and Mr. H. N. Muller, both of whom added many interesting details to the discussion. Others who participated in the discussion were: Messrs. S. P. Grace, F. W. Andrew, and J. S. Lacock. A number of representatives of municipal councils were present. About 125 members attended the meeting.

PITTSFIELD SECTION.

The Pittsfield Section held a meeting on April 16, 1909, at the Hotel Wendell, at which Mr. H. H. Barnes, Jr., of New York City, gave a talk on " The Electric Transportation Facilities in New York City." Seventy-one members were present. To give an idea of the problems involved in handling the steadily increasing passenger traffic in New York City, a brief outline was given of conditions as they exist at present, which doubtless are unequalled in any other city in the world. The population of the metropolitan district now numbers nearly 5,000,000. During the " rush hours " in the morning and again at night the facilities must be such as to accommodate during either of these periods, in a single hour, over 400,000 passengers. Even this, however is but a part of the total problem, for the number of passengers to be transported is increasing with surprising rapidity. It is estimated that this increase is nearly half a million a year. To provide for this enormous traffic over 1500 miles of track is already in service. Nearly 10,000 cars are daily in operation, and the electrical energy required to drive these now totals up to very nearly 325,000 kw. Huge power-houses in various parts of the city furnish this energy, in the form of 25-cycle, 11,000-volt alternating current. It is then transmitted to numerous sub-stations, where by means of transformers and synchronous converters it is transformed into direct current at about 600 volts, and distributed to the surface, subway, and elevated lines. To illustrate the enormous amount of coal which must be burned to keep this system in operation it was pointed out that a pound of coal burned at one of the power-houses was sufficient to carry one passenger two miles. The number of passengers carried by all the lines last year was in the neighborhood of 1,400,000,000.

An interesting description accompanied by lantern-slides was given of the equipment on the New York Central, the New York, New Haven & Hartford, and the New Pennsylvania underground system. The lecture closed with a description of the general methods now used in handling the traffic over different routes, and an outline of some of the plans which are now under way for taking care of the ever increasing travel. Before the lecture an informal dinner was held in honor of the speaker. Those present were: H. H. Barnes, Jr., Joseph Insull, W. A. Hall, P. W. Power, C. W. Sponcel. Stephen D. Field, Bernard Hoffman, G. Faccioli, C. A. Kelsey, I. P. Thompson, and H. W. Tobey.

Mr. Thomas D. Lockwood, patent expert and manager of the patent department of the American Telephone & Telegraph Company, Boston, Mass., was the guest of the Section at the meeting held in the Hotel Wendell on May 7, 1909. Mr. Ralph W. Pope, of New York, secretary of the Institute, and Mr. Stephen D. Field, of Stockbridge, Mass., were also guests at this meeting. Mr. Lockwood was the principal speaker. His subject was " The Satellite System of Primary or Pioneer Inventions." At the close of Mr. Lockwood's paper, Mr. Pope spoke briefly on the growth and progress of the Institute, and touched also upon the program which has been prepared for the annual convention at Thousand Islands. The following gentlemen were present at the dinner which was given before the meeting: T. D. Lockwood, R. W. Pope, C. C. Chesney, F. R. Whittlesey, W. A. Hall, J. Insull, G. Faccioli, Bernhard Hoffman, and H. W. Tobey.

PURDUE UNIVERSITY BRANCH

A meeting of the Purdue Branch was held April 13, 1909, Vice-chairman Ong presiding, with an attendance of 21. The topics discussed were of interest chiefly to telephone men. Mr. H. W. Smith, who has had considerable experience with the common-battery system of the Citizens' Telephone Company, Kokomo, Ind., gave a talk on " Telephone Troubles." He dealt with the practical side of the work. In part, he said: " In the office all troubles are reported to a trouble clerk. The trouble clerk keeps a permanent record of all cases, and makes out a trouble ticket for each, giving the telephone number and the address of the ailing instrument, the cable pair on which the line was working, the nature of the trouble, and any other data helpful in clearing the case. The ticket is first turned over to the wire chief. The wire chief tests the line to see whether the trouble is in the office or outside; if inside, the ticket is turned over to the trouble shooter. If the trouble shooter finds the trouble in the instrument, he brings it in to the instrument man; otherwise he clears it himself. Whoever clears the trouble returns the ticket with his O.K., to the clerk, who makes a final test of the line, and if it is found in good condition, records it as cleared." Mr. Smith then related some interesting experiences in his work as a telephone trouble man. He explained how troubles are located and cleared on both inside and outside work, and cited examples of the troubles most frequently met with.

Mr. G. S. Cooprider, who has had a varied experience in toll-line construction, gave a practical talk on "Telephone Construction." Some of the points he brought out are the following: A toll line must always be in working order, and especially is this true between important cities. The quality of construction depends upon the length of the line and its importance and also upon the competition with other lines. The route chosen is always as short as possible, and wherever practicable is made to follow good roads, in order to keep down the cost of maintenance. A telephone line is kept away from alternating-current transmission lines if possible, because of the inductive effects of the latter. Mr. Cooprider told how pole lines are built, bringing out many valuable points to be observed in order to secure substantial work. He then dealt with cable troubles, and mentioned many ways in which these may arise, also explaining the methods of clearing them. He gave some practical methods of locating troubles without resorting to resistance measurements.

SAN FRANCISCO SECTION

The San Francisco Section held its regular monthly meeting in the building of the Pacific Gas & Electric Company, on April 23, 1909. The By-Laws Committee presented for consideration a set of by-laws to govern the Section, which, with some amendments, were adopted. The papers for the evening were to be on the subject of "Electrolysis", but the work on the by-laws was of such length that the papers could not be touched. A meeting in the near future will be devoted to the subject.

SCHENECTADY SECTION

At a meeting of this Section held on April 8, 1909, Mr. E. B. Merriam, of the General Electric Company, gave an entertaining talk on "High Power Protective Devices", illustrating it with a splended collection of lantern-slides, by means of which he showed clearly the pioneer and recent developments in fuses and switching devices, bringing out particularly the viciousness of the electric arc under many conditions, and the difficulties encountered in rupturing it satisfactorily.

Mr. C. E. Eveleth added greatly to the interest of the occasion by his discussion of Mr. Merriam's paper, which he supplemented with an account of many of his interesting observations. Mr. Eveleth's remarks were followed by a general discussion in which a large number of members participated The attendance numbered about 150.

On April 22, 1909, Dr. S. A. Moss, of the Lynn works, delivered an interesting lecture on "Centrifugal Compressors." In the first part of the paper he showed a number of lantern-slides illustrating the general arrangement of such compressors. In the second part he gave an outline of the theory of the compressors, describing the similarities and differences between ordinary steam turbines and the compressors. In connection with this he also indicated the principles involved in the ordinary blowers, rotary compressors, and reciprocating pumps. By means of black-board illustrations he gave an outline of the theory and the method of calculating the compressors, and concluding the lecture by showing a number of important details in their construction, and some cross-section views of domestic and foreign turbine compressors. About 150 members were present at the meeting

SEATTLE SECTION

The meeting of this Section held April 17, 1909, was the second meeting to be devoted to the subject of industrial power. There was a total attendance of 30. Chairman Harisberger reported that it had been decided by the entertainment committee to coöperate with the Northwest Electric Light & Power Association, and that a three-day session at the Alaska-Yukon-Pacific Exposition, to be known as " Electrical Days ", had been recommended by the joint committee of the two societies. The dates of this session will be September 6, 7, and 8, 1909. Every effort will be made to obtain good papers for this session, from local members and visiting engineers. At the conclusion of the business meeting Mr. Allen E. Ransom presented a paper entitled " Application and Control of Electric Motors." Mr. Ransom pointed out that electric drive is almost invariably indicated as economical wherever the load-factor is low; that is, wherever the service is intermittent or highly variable. He stated that direct-current is preferable where frequent starting and high starting torque are necessary, but that alternating current is best suited to continuous operation, varying loads, and infrequent starting conditions. The induction motor is, in Mr. Ransom's opinion, one of the most simple and rugged of industrial machines. Considerable interest was evoked by the statement that variable-speed alternating-current motors were now in use for elevator work in Seattle and vicinity. He declared that under the best conditions full-load torque was obtainable at starting with only 1.25 times normal full-load current. Mr. C. A. Whipple, of the U. S. Navy Yard at Bremerton, stated that a rough test of the 20 h.p. and 30 h.p. motors now operating elevators at the yard indicated that they were delivering full-load torque at starting. Varying the secondary resistance was the method preferred for obtaining speed variation, and combinations of this method with a change of primary voltage, either by auto-transformers or by variable resistance in the primary, were also used. A general discussion followed the presentation of the main paper.

At the close of the discussion it was announced that the next meeting would be held at the University of Washington in order to enable Professor C. E. Magnusson to illustrate his paper for that meeting on " Effects of Electrolysis in Reinforced Concrete."

STANFORD UNIVERSITY BRANCH

The Stanford University Branch held a meeting on May 4, 1909. The following officers were elected for the ensuing year: Chairman, C. L. Bradley; secretary, C. P. Taylor; treasurer, J. B. Moorhead; librarian, F. T. Parker.

UNIVERSITY OF TEXAS BRANCH

The regular monthly meeting of the University of Texas Branch was held on March 26, 1909. Fifteen members were present. Chairman A. C. Scott gave an account of his trip to New York to attend the Institute's Twenty-fifth Anniversary Dinner, March 11, 1909. In the course of his trip Mr. Scott visited a number of northern universities, which added considerably to the interest of his remarks.

The April meeting was held on April 23, with 16 members and one visitor present. The program for the evening consisted of two papers and the review of an Institute paper. The first paper was presented by Dr. W. T. Mather, professor of physics at the University of Texas, on " Lightning and Lightning Protection " Many interesting facts were brought out in the paper. and quite a lengthy discussion followed. The second paper was presented by Mr. Edwin Oram, whose subject was " Circuit-Breakers." The program was concluded with a review of the Institute paper entitled " Stability in Electric Lighting Circuits." After adjournment refreshments were served.

TOLEDO SECTION

At the regular monthly meeting of the Toledo Section held Friday evening, May 7, 1909, Mr. John D. Noyes, of

Grand Rapids, Mich., spoke on "Industrial Application of the Induction Motor." The principles of operation and results obtained from different designs or types of machines were given attention, and the speaker gave his conclusions as to the adaptability of the alternating-current motor of to-day to many commercial conditions. Chairman McKay opened a discussion on the starting and control of alternating-current motors. A number of questions bearing on the subject were answered by Mr. Noyes.

URBANA SECTION

The April meeting of the Urbana Section was held on Wednesday evening April 28, 1909, with 30 members and visitors present. Professor Paine gave a brief history of the development of the transformer, after which Mr. A. Guell gave the results of a test of a 3-kw. transformer. This transformer, which is of the shell type, represents the most recent development of one of the great electrical companies, and weighs about 150 lb. The high-tension winding is wound concentrically between two low-tension coils. The high-tension winding has 1480 turns, and the secondary has 148 turns. The normal frequency of this transformer is 60 cycles, but its design permits of its use on circuits having frequencies varying from 50 to 140 cycles. The normal voltages are 1100/2200 and 110/220. The core loss at 60 cycles, 110 volts, is 30 watts, of which 80 per cent is hysteresis, and 20 per cent eddy current loss, while at 120 cycles, 110 volts, the total loss was 216 watts, the hysteresis loss being 72 per cent of the total. The efficiency of the transformer is high, at 25 per cent load being 95.7 per cent, and at full load 96.7 per cent. The all-day efficiency, assuming three hours full load, was 90.6 per cent.

Mr. W. C. Maddox then gave an abstract from a paper on "Electric Heating Devices", in which he gave some interesting figures as to the cost of cooking different kinds of food, as determined by extensive experiments. These figures vary widely for different classes of cooking, the use of electric ovens and heating large quantities of water by electricity having been found to be very expensive at the ordinary rates charged for electric power.

WORCESTER POLYTECHNIC INSTITUTE BRANCH

A meeting of this Branch was held in the engineering building, April 16. Mr. O. H. Escholz gave an abstract of Dean Herman Schneider's paper on "Fundamental Principles of Industrial Education", presented at a recent meeting of the Institute. Mr. B. R. Shover's paper on "Industrial Application of Electric Motors" was abstracted by Mr. Edward Early, who gave a general description of the Indiana Steel Company's plant at Gary. In discussing the paper, Mr. C. E. Putnam considered the prime movers, and Mr. R. T. Pollock dealt with the electric equipment. Lantern slides served to add to the interest of the paper.

Personal

MR. J. M. FRIED is special lamp salesman for the General Electric Company, Harrison, N. J.

MR. L. P. PERRY, formerly of Warren, Ohio, is power engineer of The Connecticut Company, and is located in the Waterbury, Conn., district.

MR. GEORGE STANTON ROSE has left the engineering department of the General Electric Company at Schenectady, N. Y., to take up work in the New York office of the same company.

MR. G. WALTER McIVER, JR. has resigned from the General Electric Company and has taken a position with the Public Service Corporation of New Jersey, as field engineer.

Mr. Herbert F. Fox has been transferred from Fort Bayard, New Mexico, to Fort Meyer, Va., to prepare plans and specifications for the installation of an electric lighting system.

Mr. Frank C. Smallpiece, until recently connected with the Canadian General Electric Company in Toronto, has been appointed assistant manager of the Montreal office of the same Company.

Mr. C. W. G. Little, of the British Electrical Federation, has removed from Donington House, Norfolk Street, Strand, London, to Electrical Federation Offices, Kingsway, London, W.C.

Mr. T. N. Lide, formerly with the main office of the Westinghouse Electric & Manufacturing Company, has been transferred to the New Orleans sales office of that company.

Mr. R. F. Pierce, former manager of the Minerallac Company, of Chicago, has resigned to take the position of sales engineer with the Excello Arc Lamp Company, New York City.

Mr. Edmund Lang, who for five years held an executive position with the Wheeler Condenser & Engineering Company, has been placed in charge of the repairshop of the Crocker-Wheeler Company, Ampere, N. J.

Mr. Henry M. Fussell, Jr., in the signal department of the Pennsylvania Railroad Company, has been transferred to the Pittsburg division of that company, as second-year signal apprentice. He is located for the present at Summerhill, Pa.

Mr. S. J. H. White, formerly electrical engineer of the Texas office of the Nernst Lamp Company, has resigned his position to accept one as electrical engineer of the apparatus department of the Hobson Electric Company, Dallas, Texas

Mr. William A. Barstow has resigned his position as superintending electrical engineer, Union Iron Works, San Francisco, Cal., and accepted an appointment in the U. S. Navy Department as master electrician, manufacturing department, navy yard, Mare Island, Cal.

Mr. Chester Lichtenberg has been transferred from the testing department of the General Electric Company at Schenectady, N. Y., to the switchboard engineering department of the same company, and for the present will remain in Schenectady.

Mr. Gardner Rogers, formerly general superintendent of the Minneapolis General Electric Company, Minneapolis, Minn., has taken a position as manager of Houghton County Traction Company and Houghton County Electric Company, Houghton County, Michigan.

Mr. Claude M. Janes has resigned his position with the Juanita M. & M. Power Company, of Huntingdon, Pa., as superintendent of stations, and accepted the position of superintendent of stations with the Connecticut River Power Company. He is now located at Brattleboro, Vermont.

Mr. H. R. Stuart has resigned his position as chief engineer of the American Telegraphone Company, which he has held for the last three years, to accept a position with the De Forest Radio Telephone Company of New York. He will have charge of experimental work on the Great Lakes.

Mr. J. A. Brundige, who for the past six years has been associated with the Ontario Power Company of Niagara Falls, as an assistant to Mr. V. G. Converse, has recently accepted a position in the engineering department of the Hydroelectric Power Commission of Ontario, at Toronto, Ont.

Mr. E. C. Newton, engineer of the United Wirelesss Telegraph Company, has completed the erection of a wireless station at Tampa, Fla., and has been transferred to the northen division, with an office in the Harvester Building, Chicago, in charge of erection of stations in the Great Lakes region.

Mr. Frank T. Clarke, for a number of years inspecting engineer for the Commonwealth Edison Company, and Sargent & Lundy, of Chicago, has severed his Chicago connections and is now with the Pacific Gas & Electric Company, of San Francisco, in the operating department of the steam and gas engine section.

Mr. M. Curry Turpin has resigned his position as superintendent of the Auburn Light, Heat and Power Company, Auburn, N. Y., and associated himself with the Public Service Commission, First District, New York City, as electrical engineer. He is engaged on the appraisal work of the Brooklyn Rapid Transit Company.

Mr. Arch K. Wood, who for the past three years has been with George R. Wood, consulting electrical engineer, of Pittsburgh, Pa., has resigned that position and accepted one with the New River & Pocahontas Consolidated Coal Company, as electrical superintendent of the Gentry plant.

Mr. Roy H. Adams, assistant electrical engineer, signal corps, U. S. Army, has been transferred from the Department of the East, New York City, where he was an inspector of insulated wires and cables, to the Department of California, San Francisco, California. His work there will be in connection with the system of fire direction and control.

Mr. George W. Cravens has opened an office as consulting engineer in the Fort Dearborn Building, Chicago. He will handle the merchanical, electrical and structural design of power plants, design special apparatus, either mechanical or electrical and will undertake the invention and development of new devices when desired.

Mr. L. H Newman, electrical assistant, Signal Service, U. S. Government, after completing the installation of the new wireless equipment at Fort Worden, Washington, will be located in the office of the Chief Signal Officer, Department of the Lakes, Chicago, Ill., where he will have charge of the inspection of all material purchased.

Mr. Thorsten Bergelin has resigned his position as assistant electrical engineer with the Utah Light and Railway Company, Salt Lake City, to accept one as district engineer with Kungl. Trollhatte Kanal—och Vattenverk, Trollhattan, Sweden, where the Swedish Government is building a hydraulic plant of 76,000 h.p. capacity.

Mr. C. W. Bender, for the past seven years in the electrical engineering department of the Pennsylvania Railroad Company, has resigned his position with that company to accept one as commercial engineer of the National Electric Lamp Association, with headquarters at 4411 Hough Avenue, Cleveland, O.

Dr. Charles C. Garrard has resigned his position as manager of the instrument and transformer department of Messrs. Ferranti, Limited, of Hollinwood, England, in order to take that of manager of the switch and controller department of the General Electric Company, Limited, and is at present located at the Witton Engineering Works of that company, near Birmingham, England.

Mr. F. J. Cumming, who for the past two years has been engaged as engineer and manager of the telephone department of the City of Edmonton, Edmonton, Canada, has resigned his position and removed to Minneapolis, Minn., where he will devote himself to consulting engineering in the telephone field. While in Edmonton, Mr. Cumming installed the new exchange, using only the latest cable construction and equipment.

MR. E. O. GOCHICOA has tendered his resignation as superintendent of the Sultepec Electric Light & Power Company, Temascaltepec, Mexico, to become the head of the new firm, Gochicoa Ohlhausen & Company, electrical contractors, Toluca, Mexico, P. O. Box 65. He will first visit some of the large electrical plants in the United States.

MR. ALFRED K. WARREN, formerly of A. K. Warren & Company, electrical and mechanical construction engineers, who for some years past has maintained engineering offices at 14 Church street, New York City, has rejoined the General Electric Company, and is at present engaged in the turbine engineering department of that company, at Lynn, Mass.

MR. H. B. PRIESTLEY WICKS left the General Electric Company, Schenectady, N. Y., in October last to return to his home in Christchurch, New Zealand. He went by way of Canada to England and the continent, taking the steamship at Genoa for Melbourne, where he spent several weeks, and thence to New Zealand. Since his return home he has been appointed manager of the electrical department of Scott Bros.

Obituary

ARTHUR WARREN KENDALL PEIRCE, a well-known American engineer, and a Member of the Institute, died at his residence at Driehoek, Transvaal, South Africa, on April 13, 1909. Mr. Peirce had been located in South Africa since 1897. Early this spring he developed symptoms of veridigris poisoning, which was followed by an attack of bacterial malaria. The complication affected his heart, and death resulted. He was born in West Boylston, Mass., on November 19, 1873. His preliminary education was acquired in the Plymouth, Mass. high school, and his technical education by home study and experience in the engineering departments of various electrical companies. In July, 1897, he was appointed electrician to the Knights Deep, Ltd., a gold mining company in Transvaal, South Africa. A year later he became consulting electrical engineer to the Consolidated Gold Fields of South Africa, Ltd., a corporation controlling a number of mines in the Transvaal. He terminated his connection with this corporation the latter part of 1906, and after a trip to England, he returned to South Africa in April 1907 to accept an appointment with the Victoria Falls Power Company, Ltd., of Germiston, Transvaal, which he retained to the time of his death. He was elected an Associate of the Institute on June 27, 1895, and was transferred to the grade of Member on August 25, 1905. Mr. Peirce was a contributor to the PROCEEDINGS, and was otherwise active in the interests of the Institute, particularly in increasing the membership in South Africa. Besides being a Member of the Institute he was also a Member of the American Society of Mechanical Engineers, the South African Association of Engineers, the Mechanical Engineers' Association of the Witwatersrand, and an Associate of the Chemical, Metallurgical and Mining Society of South Africa. His brother Mr. T. H. G. Peirce, and his wife and family, are accompanying the remains to America for interment. Mr. Peirce had many friends in this country, he having made extensive trips through various mining regions in search of information regarding hoisting from deep mines, in which work he was professionally interested.

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A paper to be presented at the 233d meeting of the American Institute of Electrical Engineers.
New York, January 8, 1909.

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(Subject to final revision for the Transactions.)

CONDITIONS AFFECTING STABILITY IN ELECTRIC LIGHTING CIRCUITS

BY ELIHU THOMSON

The term stability in this paper refers to that condition in which the current or potential, or both, remain at a steady value. Instability implies fluctuation which may arise from internal causes or be provoked by slight changes; and the fluctuations so arising may tend to be perpetuated automatically. An example of such action is the well known " surging " in series arc-light circuits, which in the early days of development often became a difficulty.

The chief part of the present discussion will naturally have to do with the constant-current series circuits containing arc lamps operated either by direct-current dynamos, by alternating-current transformers, by reactive devices in alternating-current circuits, or by rectified alternating currents from transformers. Much that will be touched upon is already well known; but there may be some matters which are not so well known, the bearing of which may be rendered more clear. The instability due to so-called " hunting " will be left out of present consideration, which will be confined chiefly to cases in which the load conditions themselves tend to instability.

The art of electric distribution began about 30 years ago with the direct-current series arc circuit. The load was inherently unstable owing to the peculiarity of the arc resistance falling with increase of current. This form of distribution seems destined to survive for a long period, especially for street service with the later luminous flame arcs of high economy. It will also hold its place in similar service with series incandescent lamps with metallic or other high economy filaments, the nature of the resistance of which results in stability of current. Such a circuit as this latter is therefore outside of present consideration. Where in fact the load in a circuit is of the nature of "dead" resistance, stability is assured provided no other disturbing causes exist, such as speed fluctuations in driving the generators. This is of course the case in the incandescent lamp circuit, whether in series, in parallel, or in a combination of the two. In early continuous current plants of small capacity, it was, however, generally easy to note the disturbances introduced by speed irregularities, or even to count the revolutions of the driving engine, or to watch the intermittent action of the engine governor.

The coupling of machines in parallel, and the later introduction of turbine driving, have resulted in the almost complete elimination of such fluctuations and they may, therefore, be left out of consideration as having nothing to do with inherent lack of stability or with such instability as inheres to the arrangement of the circuit itself. In passing, however, it may be remarked, that sometimes in self-excited direct current dynamos of constant potential type, shunt or compound, the degree of sensitiveness to speed variations may be abnormal. This sensitiveness has occasionally been noted by designers in high-speed, high-efficiency machines of moderate capacity. In such cases each slight increment of speed raises the potential and immediately reacts to increase the field strength, in turn causing a further increase, and so on. With a slight fall of speed there is of course the opposite effect. The difficulty is exaggerated if the engine governor is a little late in making its compensations, and they are at their worst when the iron of the machine is worked at the steep part of the curve of magnetization much below incipient saturation. The remedy for this form of instability is an alteration of proportions in the design and the removal of mechanical accessory causes. By working higher up on the saturation curve the tendency to magnification of the effects above alluded to is much reduced. The greater stability secured is, of course, purchased at the cost of more copper or a less efficient field circuit, and in a compounded machine the curve of potential regulation may not be so flat.

It is fortunate that the great fall of resistance in carbon filaments occurs only at ranges of temperature much below normal incandescence, or such lamps might become a load tending to instability, as in the case of the Nernst glower, which requires the addition of devices for securing stability of current.

The metallic filament and metallized filament, having positive temperature coefficients tend, if anything, to minimize all fluctuations, but the effect is naturally very small. Some tests made with rods of fairly pure silicon seem to show that, unlike carbon, it has a positive coefficient up to about 600° or 700° cent., beyond which the resistance falls very rapidly. Had, therefore, silicon possessed the refractory character of carbon, it would probably have been an unstable load, if otherwise suitable for filaments and tried in lamps.

The Nernst lamp glower is like the arc in being an unstable load. An arc started between electrodes held at a fixed distance apart and maintained at a constant potential difference would exemplify the most unstable condition possible, but the requirement is manifestly impracticable. It would result in infinite current passing. The current would grow in value until the condition of constant potential difference assumed ceased to exist. The condition reached would virtually be that of short-circuit. While the conditions assumed above are unrealizable, they are sufficiently approximated in practice, and they emphasize the fact of the need of some current-limiting or steadying device in circuit with the arc. Several arcs in series evidently do not change the nature of the problem. By an inspection of Fig. 1, in which the curves represent the relation of current and resistance and of current and potential in an open arc with fixed separation, which curves may properly be regarded as "characteristics," the unstable condition is manifest. An enclosed arc gives substantially the same result.

It has been said with some truth that to design and construct a constant-potential dynamo that would work fairly well, was, even in the early years of the art, an easy undertaking as compared with the production of a dynamo to work a series of arc lights, involving a peculiar and little known proportioning to secure stability of current in working a load so inherently unstable. The problem was not only this, but the stable current value had to be such as was proper to the machine, one which did not involve a destructive rise of temperature in the windings; and, on the other hand, one which was not so small in value as to involve such low temperatures in the windings as to indicate that the material was not being used at or near the maximum effectiveness.

It may be instructive to trace briefly the history of the development which preceded that of the constant-potential dynamo. Early in 1879 there existed arc machines working at about 10 amperes with a dozen or more arc lamps in series, the arc pressure being about 45 to 50 volts per lamp. The carbon-filament incandescent lamp was not brought out until about the beginning of 1880. It is well known that the original dynamos in service for arc lighting, excepting a small number of lighthouse plants, operated with the permanent magnet field (Holmes and Alliance machines), were constructed to work only a single arc with commutated direct current. Such were the Gramme machines of 1876, the Wallace of the same date, and the Siemens and Brush machines of a year or so later. The arc voltage was the same or nearly the same in these, but the current, according to the size of the machine, varied widely, being in some as low as 10 amperes and in others as high as 30 or 40 or more amperes. While the current values varied somewhat as the single arc burned with varying separation of its carbon, the current at any time was stable, without surging or fluctuations, such as might have been expected from the nature of the arc resistance, which was substantially the only resistance in circuit. But there were elements of compensatory character present in the circuit. As the current in an arc increases, the section of its hot gaseous conducting flame likewise increases; the resist-

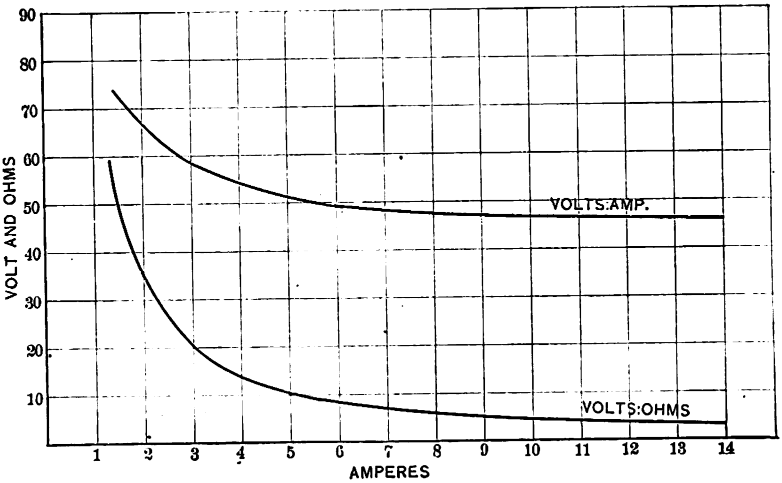


Fig.1

ance falls as more material is volatilized, and more ions are furnished to conduct the current, unless at the same time the length of the arc itself be increased to compensate therefor. Most of the early arc lamps used with these machines possessed the feature of automatically lengthening and shortening the arc following the current changes in the arc-separating lamp magnets, this tending to regulate and keep constant the current strengths. The lamps were in fact called "regulators". But while this " floating arc length ", as it may be called, assisted in securing stability, it would not have been of itself sufficient in the absence of other causes. It would have been too late in its action and of insufficient range.

When we examine the conditions of the circuit in these early machines, we find a large relative resistance in the circuit with the arc. As an example, a small Gramme machine of 1877 had a total circuit resistance including its arc, of 3.66 ohms, only 1.87 ohms being in the arc; the internal and external resistances were nearly equal. A Wallace machine had a total resistance of 7.83 ohms with only 2.77 ohms in its arc. An early Brush single arc machine had 2.95 ohms total with 1.67 ohms in the arc. This relation of resistances would of itself be ample for securing stability of current, except that the dynamos being series-field excited, were of a nature to enhance current variations in the circuit by such variations reacting at full value through the series field. The machines would on this account be more likely to have unstable current. We now know that in such cases the high armature reaction allowed, and the amount and kind of iron and its nearness to saturation, were potent factors in the stability which existed. At the time these machines were designed very little was known of these matters, and the success obtained must have been largely the result of " cut and try ", the experimental method. It was certainly easy to make the mistake of using too heavy iron sections, less armature reaction, less saturated field, with the result of using much less copper and obtaining even a more efficient machine for an equal energy output, and a better design if it had to work over dead resistance, but one which with an arc for its external work or load would not attain stability in current until the value was so large as to overheat and destroy the structure in a short time. The problem was the more difficult when later it was to be designed for a series of ten or more arcs, for in that case the steadying effect of internal resistance, so potent in the case of the single arc machines, could no longer be counted upon, such resistance falling more and more in relation to the external resistance with the size and increased capacity. In machines of thirty to forty arc lights capacity in series, the external resistance might bear to the internal a relation of approximately 10 to 1. There still remained the regulating effect of the lamp magnets giving a "floating arc length", and this action of the so-called regulators or lamps was the more important as in the larger machines the time-constant of the circuit increased, giving more time in which the lamps could act to extend and shorten the arc lengths. When surging or instability took place it was marked by a lower rate of variation in the large machines than had been the case in the smaller ones, and consequently the period in which the lamps could act was more favorable. In series dynamos of large size the field magnet reactance is naturally large, and mechanical adjustments of arc length were possible on account of the resultant sluggishness of the current variations indicating instability. There was, however, a more important property, the full significance of which was only realized at a later date.

Dr. John Hopkinson in 1879 called attention to the method of plotting curves, afterward called "characteristic curves" by Marcel Deprez. It was shown that by a study of the characteristic of a series dynamo the condition of stability or instability of current when working an arc in its circuit could be predicted. It is not necessary to repeat the work done by various investigators in the study of these curves. Suffice it to say that the conclusions as to instability are evidently modified somewhat under the conditions above pointed out, where the circuit has high reactance and there is time for the lamp mechanism to act in changing the resistance in circuit—increasing it when owing to an increase of current it tends to fall in the arc, and decreasing it when the current tends to die out owing to the higher arc resistance which follows a diminished arc current.

At one time series direct-current circuits made up of what were known as "short arcs" as distinguished from "long arcs" were employed in lighting to a considerable extent. In these short arcs the carbon electrodes were run so close together that there was but little appearance of any arc-stream between them. The arcs were hissing arcs, giving out continually a frying sound and frequently dropping out mushrooms of graphitic carbon which accumulated on the negative or lower carbon. The light itself was yellowish and came largely from the highly heated ends of the carbons next the slight separation or imperfect arc. In practice the current was about double that of the normal long arc, the voltage at the arc was about one-half. With the long arc the current was about 10 amperes and the voltage 45 to 50. In the short arc these amounts were approximately 20 amperes and 25 to 30 volts. Comparatively, the light production for a given energy expended was lower in the short arc. Reasonable life of carbons was only obtained by using extra hard sticks heavily copper-plated. The line losses formed a much higher proportion of the energy supplied. Unless the copper section were quadrupled in the case of the short arcs as compared with that used with the long arcs, the same loss per mile could not be attained.

This matter is, however, aside from our subject and is mentioned only as indicating one of the reasons for the non-survival of the type. So far as stability is concerned, however, since the lights were in considerable measure like dead resistances, it was far more readily obtained; it did not depend to such a large degree on the characteristic of the dynamo. So far as the writer is aware, these short arcs or semi-incandescent arcs were the only ones ever successfully run in series on shunt-excited arc dynamos; machines in which the proportioning was much more easy and more akin to that of constant potential types. Despite the fact that a greater efficiency in the dynamo itself could be reached, the system gradually went out of use. It is readily seen that where the arcs were so short as to be only incipient arcs, the regulating effect of the series magnets of the lamp mechanism was quite important in determining the strength of current used. Slight increase or decrease in the separation of the carbons gave a larger change in the working resistance as also in the light. A similar extent of movement of electrodes toward or from each other in the long arc would scarcely have any effect. The floating arc condition was then quite essential to practical operation of these short arcs. The lamp mechanism was indeed a " regulator " in this case.

The various forms of series arc lamps involving differential lamp magnet mechanism of one or other type secure in greater or lesser degree the floating arc condition as distinguished from the " fixed separation ", a feature of some types. As exemplifying the importance of this regulating feature upon current stability, the writer may perhaps be permitted to recall an early experience in arc dynamo design. The first series arc machine designed and built under his supervision, was also the first dynamo having the three-coil (star three phase) winding with three-segment commutator. This machine, at a speed of 750 rev. per min., ran a series of eight lamps at 10 amperes, with 45 to 50 volt arcs, and survived room temperatures of a bakery in the midsummer of 1879 in Philadelphia, the thermometer on the wall nearby showing sometimes 120° up to 140° fahr. in the early evening with the ovens in full operation. The machines had been carefully proportioned in the light of all available information which could be discovered at the time. There were very little to guide one in this task. Nevertheless, the current of the machine was stable at the current for which it was designed, although no experimental machine had preceded it. Further, there was no change needed in the windings and it remained in service for years thereafter.

Several similar machines were made after the trial of this first one. Following these there was constructed in 1880 a small compact machine for a circuit of 16 arcs in series, but the proportions were less conservatively chosen, and the armature strength was less in proportion to the field, so that regarded from later standpoint the armature reaction was too small to give a proper droop in the characteristic at the current value of 10 amperes, for which it was designed. The iron sections were also liberal. It was found capable, when driven at 800 rev. per min., of maintaining its full quota of lamps, 16 in series, but although the lamps had the series magnet regulating feature, the current was decidedly unstable, and only became so at higher values, about 15 amperes, too high for the safety of the windings. It was observed, however, that if in the circuit there was introduced a single supersensitive lamp, or one in which comparatively large extensions or shortenings of arc length followed quickly upon minor current changes, an artificial stability was produced, which, in spite of the evidently unsuitable characteristic, as now regarded, allowed the lamps to be operated at their intended current of 10 amperes, or even less. The behavior of the dynamo as to heating and efficiency, etc., was then satisfactory.

On account of the relatively high duty of the machine, less weight of wire and cost, it became actually a debatable point whether the supersensitive regulating lamp might not be shut up in an iron box and maintained as a permanent part of the circuit in practice. Later work, however, developed the fact that by changing the manner of commutation, the same machine became quite stable at the current intended, but at a sacrifice of output which could only be met by running at a somewhat higher speed. Naturally the stability obtained was accompanied by a somewhat lowered efficiency, but when attained was sufficient to render the circuit independent of any adjustment of arc length by the magnets of the lamps, except that of feeding as the arcs were lengthened by consumption of carbons. The actual change in the commutation made as above referred to consisted in rearranging the brushes of each pair, positive and negative, around the commutator from what was called forward regulation position to that which became standard in the Thomson-Houston arc machines afterward built. In the forward regulation the slots in the three-segment commutator were straight and parallel to the axis, in which case a pair of connected brushes on each side separated by a definite angle was used. Sometimes a single brush at each end of the diameter of commutation was applied, and the slot between the commutator segments offset so as to cause the segments to overlap or cover considerably more than 120° each, giving like results in commutation. In the later method, and that which became standard, there were two pairs of brushes. The commutator was made with straight slots parallel to the axis, and a positive pair of brushes placed on one side, and the negative pair on the other side. The brushes of each pair were spaced apart 60°, so that virtually a segment of the commutator was in contact with the positive or negative brushes through 180° in the full-load position. In regulating for a decreased number of lamps in series, the brushes in forward regulation were moved progressively forward, while in the later method the forward brush of each pair was adjusted forward only as far as to cover the spark developed, while the rearward brush of each pair was moved backward to the position where the same value of current was given to the circuit. It was found that if in either form of regulation the current was stable at full load it never became less so on diminished load, but rather more stable. This was to be expected. It is interesting to note in passing that if the arrangement of the brushes was intermediate between that of forward regulation and that of the later standard placing referred to, the circuit was characterized by great instability, so great as to make it impracticable to use the machine at all for an arc-lamp load.

These matters were, of course, the result of experimental trials of available apparatus. The explanation is that the needed droop in the characteristic curve of the two forms or arrangements was the result of opposite or conflicting causes incompatible with each other, so that an arrangement intermediate of them was not practicable. There is no space here for a more detailed analysis, which would itself be an interesting and instructive subject. It may be noted that one of the reasons for discarding the setting of the brushes as in "forward regulation" was that the wear of the brushes tended to extend the arc of contact and virtually to increase overlap of the segments or the arc of revolution during which a segment was in contact with a positive or negative brush. This followed as a result of the tangential position of the brushes which were made of slit strips of hard rolled copper, as well known. Lack of care in trimming and adjusting the brushes would, in fact, so extend the arc of contact that instead of stability, great instability would result. This showed clearly that stability depended on a restricted arc of contact or overlap of contact between adjacent segments under the brushes. If the field were relatively strong this overlap needed to be diminished. With a weaker field and greater armature reaction the arc could be extended. In consequence of this, and for the reasons above stated, the second or later arrangement was the final one adopted.

Another and curious stumbling block so far as stability of current was concerned was met later. Several sizes of Thomson-Houston arc dynamos were designed and built at New Britain, Conn., in 1882-1883, giving perfectly stable current without dependence on the regulating action of lamps or floating arc condition. The manufacture was removed to Lynn, Mass., in the fall of 1883, with the result of importing instability of current. The same patterns and proportions were used, all elements of construction apparently being retained. A change had been made in the lamp mechanism whereby there was now no longer any dependence of arc-length on the current fluctuations, the control of arc-length and feed being obtained by a derived circuit or shunt potential magnet only. At first it was thought that this change in the lamp mechanism was the reason of instability, and as assisting to that conclusion, experiments showed that the Lynn-built machines could operate a circuit of lamps having differential magnets (differential lamps) smoothly, and without instability. These were the old so called D lamps; the new lamps being the old well known M & K type.

As a remedy for the trouble, and one resorted to while the true cause was being investigated, there was established a short-circuit band of copper wire around the field cores parallel to the winding. This device at once gave stability to the current with both types of lamp. Meanwhile it had been determined that machines built in New Britain could operate with a stable current with either type of lamp in circuit, showing that they at least were independent of the floating arc condition, or did not need the regulating effect of the lamps to insure stability. It was further found that machines built in Lynn from castings made in New Britain gave stability with either type of lamp. This led to the suspicion that in the cast iron itself lay the true cause. Analysis showed manganese in the New Britain iron and very little in the Lynn foundry iron. Special melts made in Lynn with the same mixtures of pig iron as were used in New Britain gave at once stable current and ended the difficulty without recourse to the closed copper band on the field, which demanded the sacrifice of considerable copper.

If anything will serve to show the pitfalls to which the arc-dynamo designer was subject, the above incident should suffice. The difference in the iron was evidently a difference in magnetic stability, rigidity, or hysteresis. In a dynamo machine the iron of which is magnetically stable or rigid, as when the hysteresis loop is wide, there is an absence of response to minor current fluctuations which response is one of the causes of instability in series-wound machines. Put differently, it may be that there is an *ascending* characteristic curve, derivable from current and potential determinations while these are increasing, and a *descending* characteristic derivable from similar determinations, while these are diminished or diminishing. The greater the difference between these two the greater the stability of current, and the further down toward the origin one may work without instability. In machines with large iron projections on the armature core, such as the Brush arc machine, it is likely that there would be but little difference ascending or descending, owing to the magnetic vibration accompanying the operation of the machine; but it is conceivable that with steadily-driven, smooth-core armatures the hysteresis of the field iron would be a controlling factor. Doubtless, in the case above described, a study of the magnetic qualities of the two irons would have disclosed the difference, so important in its practical effect. But it was then too early and there was too much else to be done at that time.

In apparatus in which potential differences of thousands of volts had to be maintained with only a single slot in the commutator between the brushes at such great potential differences, it can readily be understood that flashing or arcing over a slot might short-circuit or reduce the line current so much as to introduce a different kind of instability. Such a flashing or arcing in the slot was of the nature of an alternating arc. A segment of the commutator left the brush with a small trailing spark, showing a diminishing current reaching zero at a small distance in advance of the brush. Immediately thereafter the potential of the segment was reversed and attained a high opposite value, which, as an alternating arc, would jump the zero current position, especially if any heated gas remained in the slot. The writer has been frequently credited with having adopted as a bold expedient the well known air-blast mechanism to blow out the sparks at the commutator. Nothing could be further from the fact or more mistaken. The real function of the air blast was to ensure the non-existence of heated gas at the zero current, to replace it with cold air and prevent the possibility of the next alternation re-establishing the arc and short-circuiting the commutator over the single slot between positive and negative brushes. The action to be secured was carefully reasoned out in advance of its trial and application. Without it the instability of circuit conditions would have rendered operation entirely impracticable, owing to incessant alternating arcs between commutator segments. Although these considerations apply to apparatus which is rapidly being replaced by other means of distribution, the writer feels justified in here presenting them as matters of history not generally understood.

The arc-light dynamo devised by Mr. Chas. F. Brush was the pioneer machine in series arc work, and it is proper to inquire as to the features which made it successful so far as stability of current was concerned. It was early shown to possess a drooping external characteristic, but it is safe to say that in the earliest types there was still dependence upon the regulating feature of the lamp or floating arc condition. The lamps were of the differential type. It is also a fact that the peculiar property conducing to stability both in the earlier and more recent designs was largely due to an almost critical proportioning of the proper extent and relative sections of the pole horns adjacent to the armature on each side. In a conversation with Mr. Brush in 1878, the writer remembers that he laid emphasis on the fact that even in the single arc machines then before us, a comparatively slight variation in spacing or the arc covered by the pole pieces would destroy the stability of current, so that, as he said, he could do nothing with the machine. This was before the day of characteristic curves. The later Brush machines of large capacity for multicircuit work up to 125 arc lights or more, many of which have been built at Lynn, Mass., depended more than ever on the close proportioning of armature and field, and more particularly upon the form section, material, and arc covered by the pole horns. By careful adjustment an external characteristic curve having an almost vertical droop at a current value a little beyond the working current strength was obtained, rendering the current stable regardless of the regulating effect of lamps, and leaving but little to be done in regulating for variations of number of lamps in circuit.

There is given in Fig. 2 an approximate showing of the relation of external characteristics of three Brush machines of different periods. The curves are not accurate, but merely indicate general types. Curve A shows the general form of characteristic of one of the earlier bipolar types. Curve B is that of a later type of larger capacity (125 arcs in series) built in Cleveland. Curve C gives the approximate curve of a still later machine of the same capacity built in Lynn, the two latter machines being of the four pole type. There was a progressive saving in copper obtained. In the machine of curve A, the copper was approximately 50 lb. per kilowatt output; in the machine of curve B, about 40 lb. and in the machine of curve C, about 28 lb.

In Fig. 3 are given three characteristics taken from one of the most recent Brush machines constructed for working magnetite arc lamps at 4 amperes at a total circuit voltage of 15,000; multicircuit plan. In regulation the machine is shunted more or less and brushes adjusted automatically for variations of load. Curve A with a little over 15 per cent of the field current shunted and brushes fixed indicates that the normal current point is well over on the droop which at 5 amperes corresponds to short-circuit or no voltage. With curve B, or unshunted field, the normal current point lies on the horizontal part of the curve which then droops rapidly at about 4.75 amperes and would indicate a probable short-circuit current about 5.5. Curve C shows the normal current value of 4 amperes at no voltage and indicates the condition when all lamps are shunted and the field shunted, in this case to the extent of 34 per cent of its current. Curve A shows ample stability. Curve B indicates an approach to instability, probably capable of being prevented by the regulating feature of the lamps or floating arc condition. Curve C is, of course, an indication of most perfect stability and it will be readily understood that as the load is cut off in passing from A to C the margin of stability will increase steadily.

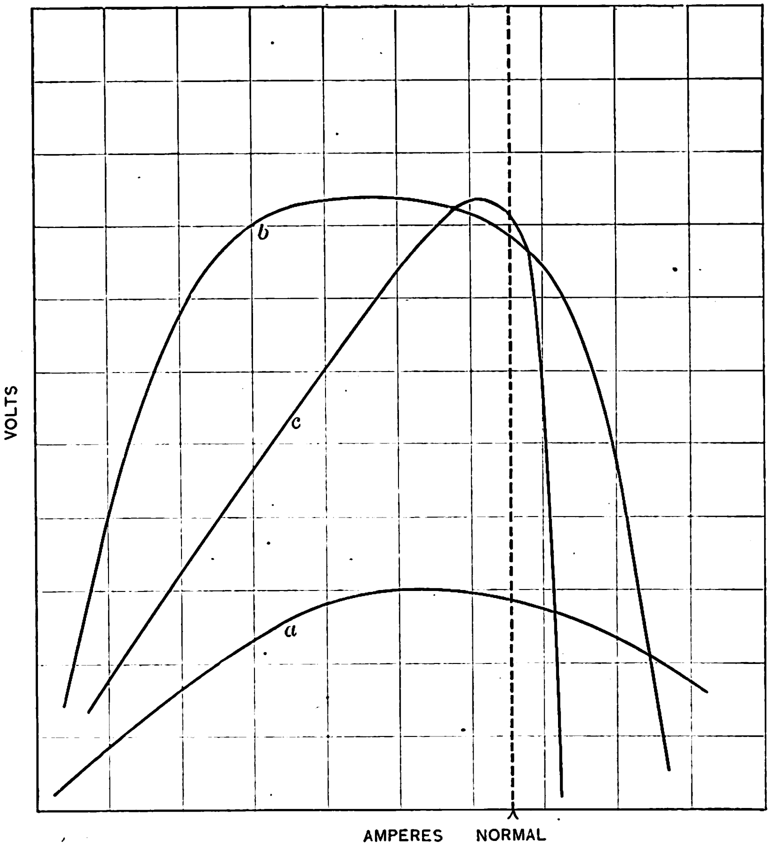
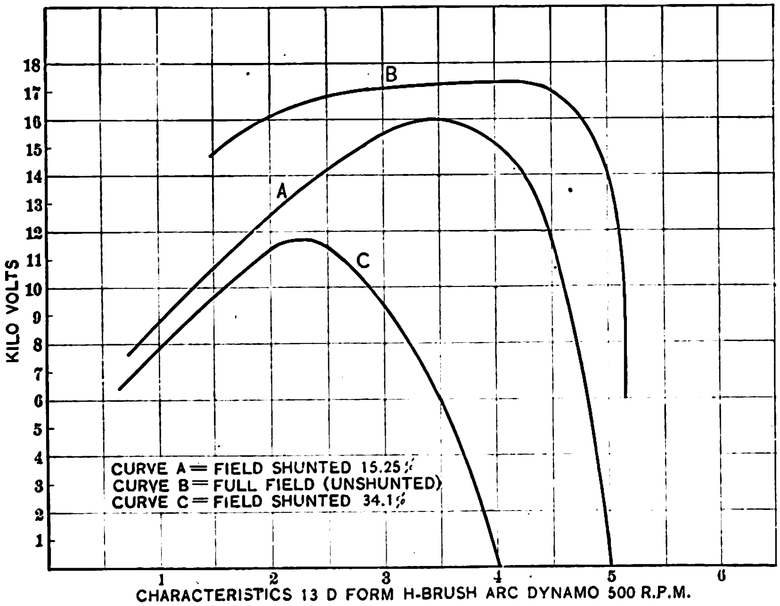


Fig. 2

It is interesting to note that in most of the early Brush machines there was applied around the field cores a closed copper band to increase the stability or prevent surging. The temporary use of this expedient in the Thomson-Houston construction has been alluded to. The closed band served to render the field magnetism less sensitive to quick changes occurring in the current of the machine, by permitting the induction of opposed currents in the band. The magnetism was thus rendered more stable and the changes in it more sluggish.

The complete theory of the various types of arc dynamos has not been worked out, and much of the designing has been of necessity of the cut and try order. The later work on the Brush dynamo has been ably carried out by Mr. C. M. Green at Lynn, which machine on account of lending itself readily to multicircuit working is still constructed, though the output is now relatively small. On account of the great dependence of the working and current stability upon the relations and proportions of the pole horns, it may almost be characterized as a " pole piece " machine in contradistinction to one in which there is either an absence of pole horns or in which, if they exist, their form and disposition exerts no vital influence on



CHARACTERISTICS 13 D FORM H-BRUSH ARC DYNAMO 500 R.P.M.

Fig.3

the working, particularly as concerns the stability so essential where the load consists of arcs.

It seems probable that on account of the simplicity of the wiring the series, constant-current circuit will, be employed for a long period in the future for arc lighting in street service and for large spaces. The advances recently made in high-efficiency luminous flame arcs will doubtless be a potent factor in future development.

When the enclosed carbon arcs were substituted for open arcs on direct-current circuits, it was recognized that a sacrifice of efficiency of light production with a given energy was involved. This was offset, however, by the other well known advantages accruing. No noticeable change in the stability of the circuits was discovered when the substitution was made. When, however, the alternating-current open arc, itself less efficient than the direct-current arc, came to be enclosed it was found that the sacrifice in efficiency was such that aside from the white color of the light of the arc there was no advantage over incandescent lamps using the same energy. It may be conceded that no artificial light equals the carbon arc in its approach to an ideal white light, or a light approaching that of the sun; and doubtless we see to better advantage with such a quality of light even at a diminished intensity of illumination.

The introduction of alternating-current arcs in lighting occurred very early, as in the lighthouse lamps before mentioned. The introduction of the so-called Jablochhoff candle in 1878 was, however, the first attempt to apply it in general illumination. The candles had some of the features of the luminous arc, inasmuch as they smoked and consumed a solid substance such as kaolin besides the carbon. The candles were operated several in a series. Little is known of the stability conditions in such circuits, but in Paris in 1878 the alternating dynamo current was not carried directly to the lamps, but the lamp circuits were operated through huge condensers in such manner that several series of lamps were fed from the single current of larger value split up through the condensers. It is possible that this use of condensers in the distribution served to limit the current values and secure stability. Later attempts to apply open arcs of the alternating type on series circuits from constant-current transformers, met with little encouragement. Not until the success of the enclosed arc on direct current had been fully demonstrated was there any considerable opportunity to make use of series alternating-current arcs. The enclosed alternating arc operated from constant-current regulating transformers gave the opportunity. The system permitted the employment in the station of generators of large capacity with constant-potential mains, to which the primaries of the transformers could be connected at conveniently located sub-stations, while the secondary arc circuits became independent, so that leaks or grounds on one did not affect the other. This was a manifest advantage.

Fortunately no difficulty arose in securing stability of current values in constant-current transformer distribution. The reactance, or more properly the general impedance of the system including the alternating lamp magnets, which themselves assist materially, resulted in a fall of potential with increased current, and the reverse, at a rate sufficient to insure stability. The characteristic curve plotted with current as abscissas and volts as ordinates would in the constant-current transformer droop as in the arc machine, but it would droop steadily from zero current outward. In other words, the potential is at a maximum with zero current, while in the series field arc machine except for residual magnetism, zero current corresponds to zero potential. Were, however, the primary and secondary coils of the transformer allowed to come too near together the condition would approach too closely that of a constant-potential transformer. The leakage magnetism between primary and secondary coils when as close together as permissible will give rise to considerable reactance values, which, as the load on the secondary is cut off, will gradually increase as the secondary is repelled to a greater and greater distance. It is necessary that the movement of the coil be effectually damped, by dash-pots or the like, or an instability due to overrunning akin to hunting will take place during changes of load. The direct-current arc dynamo with its heavy series field coils is likely to have so much self-induction as to tend to steady the current values so far as very rapid fluctuations are concerned. When, however, the field, as in the Brush machine, is shunted more or less for regulation, this influence of the field inductance is neutralized, at least to a large extent. With the alternating current-circuit there is, of course, an entire absence of such influence upon stability; but in this case the resistance and self-induction in the whole circuit traversed by the current is sufficient for securing stable values of current. These conditions giving rise to stability naturally involve a lessened power-factor in the system, and, as is well known, the distortion of the current wave in an alternating arc while not in the nature of a true lag, reduces the power-factor. It is probable also that the tendency to instability in an alternating-current arc is not so great as in the direct-current arc, for the arc undergoes extinguishment at the zero and does not relight until after the potential difference between the electrodes has reached a considerable fraction of the maximum.

In the more recent work with magnetite arcs and with lamps having electrodes which, for satisfactory operation, demand the employment of direct current, there was at one time a tendency to return to the use of motor-driven arc dynamos giving small current values and high potentials. The development of the mercury-arc rectifier and its apparent special adaptability to the rectification of small currents at high voltage has naturally led to its employment in conjunction with the constant-current transformer for securing direct currents suitable for series-arc circuits. The practical results so far obtained with oil-immersed mercury rectifiers have been so generally satisfactory as to indicate an extended future application. The new factor which has thus been introduced into constant current working may of course be the cause of disturbances and instability under certain conditions, such as too high or too low a temperature in the rectifier, change of vacuum, or momentary flashing from anode to anode indicating failure to rectify. Any cause which disturbs the circuit voltage is productive of results which may be classed as instability.

Oil bath immersion has given control of the working temperature of the rectifiers. If too low, the condition imports instability. If too high, there is danger of breakdown. Fortunately it appears that normal working demands such moderate temperatures as are easily maintained in the oil bath. Alteration of vacuum by leakage, or by gradual giving out of gas may result in the accumulation of a body of insulating gas around the anode, interfering with the normal ionized mercury vapor stream which conducts the current. This may cause a fading out of the rectified current, in turn causing the lamp to lower or drop the electrodes together, and thus again allow increase of current which again separates them, and so on; a condition of surging or oscillation somewhat akin to the instability of an arc circuit when working too close to the critical point on the characteristic. Lowered vacuum also endangers the rectifier by causing excessive stresses near the anodes, which may puncture the glass. Suitably spaced shunting gaps may be provided around the rectifier as a safeguard against excessive stresses. The temperature of the rectifier tube can also be maintained by circulation of air by a fan where oil is not used. The plant includes, besides the rectifier and constant-current transformer, additional alternating-current reactance, and a direct-current reactance in the rectified current circuit, the proportions of which are chosen to insure as far as possible steadiness in the working.

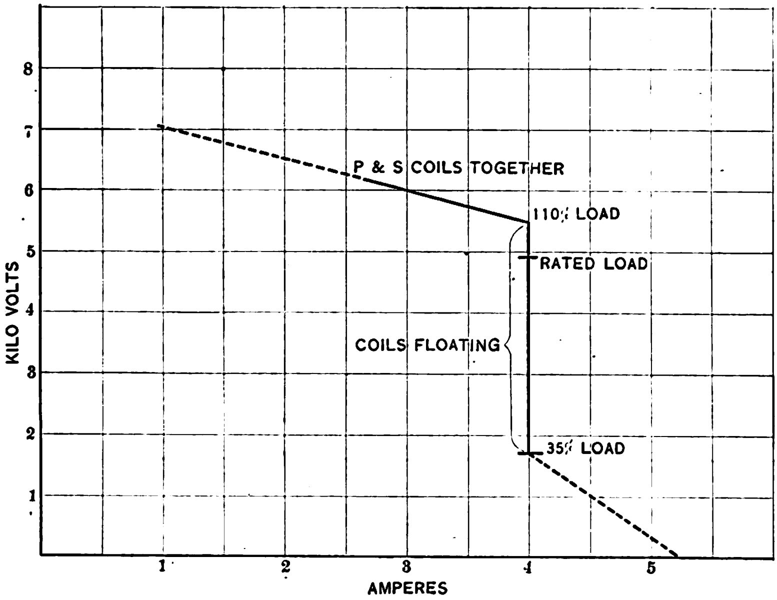


FIG. 4

If a characteristic be plotted it takes the form given in Fig. 4, which is properly the regulation curve. The vertical line at 4 amperes shows the range of constant current between 110 per cent load and 35 per cent of full load in kilovolts, the latter point corresponding to the greatest separation of primary and secondary coils as provided for in the construction of the transformer tested. Even at short-circuit the current will then not exceed 5.25 amperes. As a rule the circuit is adapted to the operation of lamps in which the arc length is either " floating " or fixed, without involving instability of current. Hence the lamps may be constructed to lift the upper electrodes and separate them to a definite distance and to drop them together at feeding, which in the case of long burning electrodes would occur very infrequently. This manner of operating was known in the early days as " drop and lift " feeding, and was probably first used on any scale in the obsolete Wallace plate lamp. As before shown, such operation requires a current which is inherently stable, as no adjustment occurs in the lamp itself. As indicating the endurance of the mercury arc rectifier itself, it may be incidentally mentioned that some of these in service have attained upwards of 5000 hours' life and are still operating. The system has the advantage of permitting arc lamps to be operated from 25-cycle circuits, and while the direct-current is then more pulsating than in the case of higher frequencies, it is still satisfactory. The power-factor at full load ranges about 70 per cent and the efficiency is about 90 per cent. Increase of the power-factor would probably result in instability of current.

Before closing, the conditions governing the stability of an arc or arcs in branches from constant potential mains may be briefly referred to.

As before stated, instability is then at a maximum and current values may rise to the proportions of a destructive short-circuit. If the regulating mechanism of the lamp extends the arc or the reverse in response to current variations, a violent surging or oscillation with extinction results. Hence the necessity of the choking-coil, whether there be one or more arcs in series across the mains. With continuous currents a dead resistance which will cause a drop of from 20 to 30 per cent of the total potential is generally inserted. The condition for stability is that the resistance shall drop the potential at the arc with increase of current at a greater rate than that caused by increase of current in the arc itself, and *vice versa*, as is well known. This involves a serious loss of energy and many efforts have been made to reduce or minimize it. It is usual to allow the floating arc to exist and in such a case the dead resistance may be cut down, if in the arc branch a large self-induction be inserted; a reactive coil which introduces a time-lag in the current variations allowing the regulating action of the lamp magnets to come into play. Better yet, if the lifting magnet be made a shunt of many turns around the more coarsely wound reactance or reactive coil (as invented by Higham) a supersensitiveness in the lamp mechanism is obtained which causes it to anticipate current changes or at least compensate therefor in increasing and diminishing the arc length and so preventing the fluctuations attaining any considerable value. Still more effective is the arrangement in which as in Fig. 5, the arc adjusting coil *C* in shunt to the reactive coil *R* is made to move in the field of the latter used as a field magnet *M*. These arrangements permit a direct-current arc to be operated between constant-potential mains with a minimum of dead resistance in series with it. Unfortunately, the saving with the carbon arc is of little practical value where a single

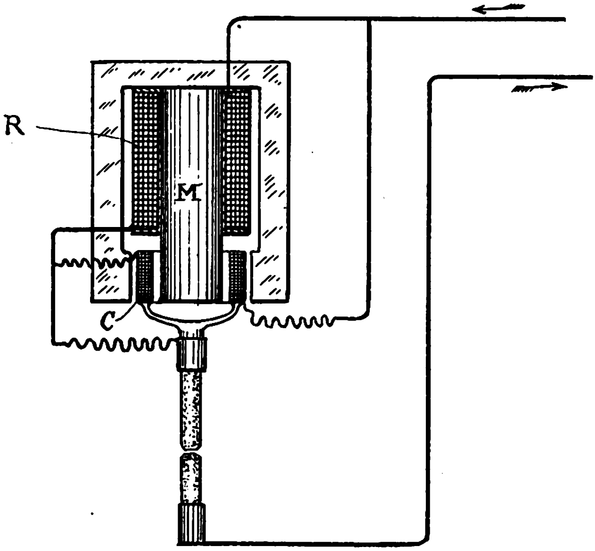


FIG. 5

enclosed arc is put in a branch across 110-volt mains. While the voltage at the arc may be thus increased from 80 volts to 100 or thereabouts, the gain in light does not correspond to the increased arc energy, on account of the comparatively low luminosity of the arc flame itself. It is possible that where the arc flame is the source of light, as in luminous arcs, the expedient may give practically valuable results, though that remains to be seen. In the case of the alternating arc across lines at constant potential, stability is readily obtained by the introduction of an impedance, or reactive coil, which need not involve any considerable loss of energy, but of course its effect is to diminish the power-factor of the system to which also the distortion of wave in the alternating arc itself may add. Both the Nernst glower and the mercury-arc lamp share with the ordinary arcs the disability of invoking instability of current unless special means are provided to prevent it. No special consideration needs therefore to be given to them in this general review of the subject.

DISCUSSION ON "A NEW METHOD OF TRAINING ENGINEERS," AND "THE RELATION OF THE MANUFACTURING COMPANY TO THE TECHNICAL GRADUATE." ATLANTIC CITY, N. J., JULY 2, 1908.

(Subject to final revision for the Transactions.)

B. A. Behrend: Permit me to discuss the paper by Mr. Alexander, suggesting a new method for training engineers by alternating shop work with college work. Let us see how difficult it would be to have such courses at institutions situated far away from manufacturing centers like Cornell, Leland Stanford, University of Wisconsin, or Pennsylvania State College. How could the students in these universities attend the lectures for one week and go into the shops for the next week, or for one month and go into the shop for the next month? There are no shops or manufacturing plants near enough in which the students could pursue practical work, and thus the proposed "Coöperative System." is altogether impossible in a large number of our universities. Furthermore, be it remembered that there are only half a dozen manufacturing companies in this country in which the variety of work is great enough to give the student an idea of the engineering and manufacturing problems arising in the building of electric motors and generators, incandescent lamps, steam turbines, gas engines, and other machinery. In small shops, confined to the making of specialties, the student is not apt to learn more than the mere handicraft. Trades have ceased to be crafts, as discoveries and inventions are constantly changing the industries so that apprenticeship to a certain trade is gradually losing its importance. Knowledge of fundamental principles alone can successfully take the place of the old apprenticeship course. The coöperative system of education, as I interpret it, in accordance with Mr. Alexander's suggestions, would effectively prevent the student from concentrating his mind on any subject whatsoever. I have never seen a complex question which could be completely solved or brought to a conclusion within a week's time or a month's time. Take a boy off the work and put him into the shop, and what is to become of the labor he has expended in familiarizing himself with the problem? Vice versa, put a boy in a machine shop or foundry and teach him for a week the kinks of the trade, and then send him back to school for another week or a month: what is to become of the labor which he has expended in familiarizing himself with his shop work? In either case the work and time spent in preparation will be entirely wasted. It is like starting and stopping, accelerating and retarding the boy's mind continually instead of allowing him to obtain a given velocity and momentum.

The term "engineer" is made to cover so wide a field that it is necessary to define it to prevent confusion. The engineer who is bred at a university should have full command of theoretical knowledge. He should learn at the university principally what he cannot learn in after life. After graduation he may obtain some practical shop experience and, if he happens to be an electrical engineer, he may pass through the two years students' course of any one of the large manufacturing companies. With some shop work during his vacations, and probably a year's shop work after graduation from high school, his training should not be held responsible if he does not become a successful engineer.

There is, however, a much wider field for men in possession of some moderate theoretical training and of good practical knowledge. A large number of electrical and mechanical engineers are needed in the manufacturing industries as foremen, superintendents, and master mechanics, to whom a long scientific training would be of little or no advantage. For the training of such men there are provided abroad technical schools, professional schools, or technical middle schools as they are called, in which such a coöperative course might be feasible. You need to give these men chiefly a practical education and enough light, as far as theory is concerned, to obtain an insight into the principles and the working of the machinery which they handle and take care of.

If we set aside certain colleges of ours for the purpose of giving a good practical education to a class of men who are not likely to be concerned in later life with the difficult and complex questions of engineering, I can see no objection to adopting a coöperative course in these technical schools. When, however, we are told that this alternating course should be introduced into our universities, permit me to say with much emphasis that I think this is the most vicious educational innovation that has been proposed in recent years.

J. P. Jackson: I have heard many times the statement that the college graduate is not prepared for his place in the world when he leaves college. In reply to this criticism, I would like to say to the practising engineers, that if such is the case, they alone are responsible. The engineering college is their servant, and they can make it what they wish. It is their duty, as practising engineers, to take a positive and actual part in the college work.

Mr. Rushmore said that in teaching, we must consider the costs and economic questions. In our technical courses we have been weak in political science, in social and economic science, and in history. I consider that general history should deal with scientific development, as much as with political and economic movements, and I want to refer the weakness in this subject to your educational committee as one worthy of consideration. Along with suitable history, extending to the end of the course, should be studies in political science.

Elihu Thomson (by letter): Mr. Alexander has so fully described the proposed plan of coöperative education for the training of engineers that it is not necessary to refer to any of its details which would naturally be the subject of modification, according to the results of experience. The plan itself or some modification of it has seemed to me to present the possibility of results of such value that it is worthy of an earnest trial. Experience only can determine its true relation to other methods and courses of education. Involving as it does the feature of allowing the student to earn reasonable pay for his shop work, it would serve as a material assistance to those upon whom the expenses of the ordinary technical school would bear very heavily, or become a preventive of the attendance of those otherwise well fitted therefor. It would act to broaden opportunity, and this is of course very desirable in these days. Naturally such an education must be limited to those who manifest a capacity for it, and it would assist the student in an early determination of his fitness or natural aptitude for various kinds of work.

The earlier this discovery or determination is reached the better it will be, serving as a guide in future development. Naturally a combined course such as that outlined in Mr. Alexander's paper cannot be completed except by an extension of time of the school period. It is assumed, however, that upon the completion of the period of six years, the student will have the very real advantage of having had contact with actual practical work and its conditions instead of requiring much time to adapt himself to them. The attitude of the engineering or manufacturing company towards the plan will depend on possible benefits, such as securing for its force a selection of men well-trained practically and theoretically.

Percy H. Thomas: Broadly speaking, the theoretical training of an engineer, in my judgment, should come properly before his familiarity with commercial work. On the other hand, he cannot get the full benefit of his theoretical training without some knowledge of commercial conditions. Since the latter part of his theoretical training is the period in which a knowledge of practical work is of the greatest importance, it would seem that the gain which can be obtained by interlinking the school training with the practical work may be obtained by overlapping the last part of the school course with the beginning of the practical work. To carry this overlapping further at the present time would appear to me, however, to be a great risk.

I notice that Mr. Alexander suggested the cutting out of the shop work at the college. I do not believe that this would be wise. The character of the training from the college shop work should be a very different thing from the practical experience in the factory. There is much about the nature of materials and the characteristics of machine tools which is gotten very imperfectly, if at all, in the factory, and is gotten very quickly in the college workshop.

The distracting of attention from the theoretical ground-work of a man's education before its substantial completion, by awakening a keen interest in the commercial work, is a great danger. I do not believe that the man before graduation should be permitted to get deep enough into the commercial work of the manufacturing company really to feel its inspiration.

If there be any advantage to a poor student, by his being able to utilize his labor in the factory, this fact is to be considered, and commended; but personally I do not believe that this consideration is a controlling factor. The dropping of the work in the factory to return to the college is an incidental disadvantage to the man who wishes to get ahead, in that whatever connection he may have gained in a certain definite line of work is thereby broken.

Morgan Brooks: Mr. Alexander has taken up this question from the manufacturer's standpoint. I desire to say a few words from the point of view of the technical school. Many of the boys entering college directly from the high school are entirely too young to do satisfactory work in a manufacturing establishment. College training for the youth is not merely mechanical drawing or mathematics, but it is the developing of character. I assume that Mr. Alexander has in mind men of twenty-one or more who lack a college training. We sometimes get boys of sixteen who need college restraint and discipline as well as physical training before they are ready for heavy work.

The difficulty of arranging alternating periods for a group of students would be very great, unless every individual were required to take the same work. Election of subjects such as German, French, English, or history, and the selection of different technical subjects as well, would be impracticable. We would find only one or two students out of twenty who would wish to take certain courses, and it would not be feasible to assign separate instructors to each of these small classes. The student would be obliged to adopt a course selected by others, and thus lose one of the opportunities of a university—the selection of subjects according to his own taste or need. By making the period of alternation the half year or college semester this objection would be greatly reduced.

College training should not necessarily be expected to turn out a productive engineer upon graduation. At first, graduates are often at a disadvantage compared with regular apprentices, but the fact that they rapidly attain success is proof of the value of a technical training. The failure of some technically trained men ought not to create surprise. Training can only increase opportunity or accelerate progress; it cannot produce an engineer from nothing. The men who are successful without college training, and we have many such, would no doubt have gained success more quickly with it. They are the kind of men to make their mark in spite of the lack of technical education,

Henry H. Norris: Mr. Alexander outlines a plan for improving technical education which differs from the standard method in that practical and theoretical instruction are separated and alternated. While it possesses many obvious advantages, from the teacher's standpoint this coöperative plan appears to ignore certain difficulties with which the educator has to contend. Although the technical student is in many ways an ideal pupil, he has certain characteristics which must be kept in mind in devising plans for improving present methods, which are the result of evolution and which are, presumably, as satisfactory as can be expected under existing conditions. In technical education the teachers must work and plan for the average student. The brilliant student does not concern them particularly, nor does the very poor student; the former looks out for himself, and the latter is automatically taken care of by a natural process of elimination. The average student is the one whose characteristics must be kept in mind in discussing any particular plan.

In the first place, the average man prefers to work with his hands rather than with his head; for example, a student will usually take more interest and pleasure in building and testing a motor than he will in calculating accurately what the torque in that motor will be when the machine has certain physical characteristics. Again, students lose interest in theory when they become very much absorbed in practical work; that is, they seem to like the practice better than they do the theory. Therefore, in technical training there should be included just enough practice to produce facts to think with, and no more; just enough facts to furnish the material for organization.

A second and important feature is that there is always a loss of time in starting up after a change in mental occupation. This is illustrated particularly in the case of vacations. There is a lag of a week or ten days after a vacation before the mental machinery gets into smooth working order. The student in taking up his work at the end of a vacation acts as if he had a large inductance, and toward the end of the term he acts as if he had a large capacity; he starts slowly, he stops quickly. During the past year at Sibley College, the problem of reducing the frequency of these oscillations or alternations of work has received careful attention. Many professors advocated terms of four months, without interruption, alternated with vacations of substantial length. The general faculty of the university rejected the plan because there was difficulty in arranging a schedule to meet the needs of all the colleges of the university, but Sibley College stood for a plan involving two complete cycles per year.

A third fact which has a bearing on the coöperative plan is that when an individual knows that a task is to be dropped, whether completed or not, at a certain time, he loses a sense o responsibility with reference to that task. This sense of responsibility is an important element in successful teaching and it should be retained to the maximum possible extent.

There has been some discussion as to the place of shop work in the college. In my opinion shop work should be kept in the college curriculum, because the shop is the laboratory for teaching the principles of manufacturing. The principles of manufacturing can be taught better in college, by competent persons, than in the manufacturing establishment itself.

Mr. Rushmore suggests another plan for improving technical education. This involves no radical departure from existing practice, but rather a more efficient use of the means already at command. In most of the colleges there exist arrangements whereby advanced degrees may be secured *in absentia*, by proper registration and examination. In many cases the present methods of administering and supervising this work need considerable improvement.

Charles P. Steinmetz: Speaking from the point of view of the college professor, I appreciate that there are many things which it would be very desirable and important to teach in college, such as factory management, shop work and languages. We could teach them if we had a college course of eight or ten years. The question is not what it would be desirable to teach in these four years, because we cannot possibly teach in four years everything that the electrical engineer should know.

It appears to me that the guiding principle, in regard to what should be taught and what should not be taught, is that the college should teach all that which the young man can never learn after leaving college, and drop all those things which the young man can learn after leaving college. The humanities, the scientific foundations of electrical engineering—such as mathematics, principles of mechanical and civil engineering, engineering mechanics, physics, chemistry—these cannot well be learned afterwards, but subjects like practical work, factory management, business administration, etc., while very essential and very important, can be learned afterwards, and usually better than in college.

Colleges have been criticised because the young men are not fit immediately to fill important industrial positions, but have to learn in practice what the college can not give them. Now from my other point of view, that of a user of young men, I do not consider this state of affairs a criticism of the college. On the contrary, if a college were to turn out young men who could immediately drop into positions in our industrial organizations, I would very strongly suspect that that college had wasted the young men's time by teaching them things which they could learn just as well, if not better, afterwards; and that, therefore, many things which they should know but can not learn afterwards had not been taught. I do not believe the college graduate should be expected to be ready to enter immediately into full engineering practice; I believe he should have all the requirements to develop in due time into a first-class engineer.

We must not forget, however, that the college is not the only educational institution. There are other important educational institutions for electrical engineers. There are trade schools and correspondence schools. They do work the importance of which many of you do not appreciate, work of the highest value, and I want to speak here for them and draw attention to them so that we may give them proper recognition.

Dugald C. Jackson: We must remember that the problem of education is physiological and psychological. Education is not one of the exact sciences. The American Institute of Electrical Engineers has had placed before it in more than one paper the very distinct difficulty which engineers find in applying mathematical equations to the phenomena of what we call the exact sciences, such as physics, and we may as well start upon the proposition that we have no basis upon which to lay even the foundation for an equation of education. We are consequently compelled to rely entirely on the experience of the past in drawing our conclusions in respect to education. This is a very unsatisfactory basis upon which to found an advance, but it is the best we have. In passing, I may say that it is as good a foundation as Watt had for his physical science at the time that he made the modern steam engine; it is as good a foundation as George Stephenson had for his physical science when he succeeded in demonstrating that steam locomotives could cope with horses and displace them for transportation; and it is as good a foundation as was possessed for their physical science by most of the great inventors who produced the fundamental processes of our present industries and brought us the kind of civilization we know today. We may therefore believe that there is no reason for pessimism because we do not yet possess a firmer foundation for our reasoning about the methods of education.

As far as engineers' education is concerned, I think we will agree that we are here looking at it as *professional* education. We will probably all of us agree that we want to see the greater engineering schools aim at producing men of tremendous worth who will go far as engineers. The lesser engineering schools, trades schools, and others, will take care of the lower grades in the engineering arts; but so far as the greater engineering schools are concerned, their educational efforts should rest on a foundation of fine, thoughtfully taught literature, history and the other subjects of " humanistic " interest, including the languages; but whatever these efforts are founded on, it is distinctly professional education that the engineering schools must carry on.

The history of engineering training has much in common with the experiences of other professional branches. The early engineers were trained by becoming articled apprentices to principals who were supposed to direct their reading in natural philosophy and the like, and at the same time give them opportunities for actual engineering work. The earlier engineering schools dealt with civil engineering. They afforded advantages over the older way because the students were required to study with greater fidelity, and practice of the old type of civil engineering could be actually mixed with the studies. The situation has been quite different with the provisions for mechanical-engineering and electrical-engineering students. School shops, however well operated, have never afforded an equivalent of the inspiration or the practice that may be derived from association with a large, diversified, and well-run manufacturing establishment. In the latter respect, the engineering schools now labor under the disabilities analogous to those pertaining to the law schools before the general study of cases and practice in the moot courts were introduced in association with the study of the philosophy of the law, and to those pertaining to the medical schools before the association with hospital and general practice was thoroughly worked out.

It seems to me that Mr. Alexander's proposition has a strong foundation of precedent resting on professional education in other branches, and that the plan is one to which it is desirable to give a full and complete trial; and it is to be hoped that arrangements can be made for such a trial to be given. I have had an opportunity to study carefully Mr. Alexander's particular proposition. I have become convinced that this plan properly utilized may do much for engineering education, as the analogous plan properly utilized has already done much for law and medical education. Such a plan would not convert the young men into engineers who would be prepared to do the work that can only be done by men of twenty-five years' professional experience, but it would afford the young men a scientific and humanistic training equal to that which they now get in the best engineering courses plus much more acquaintance with the qualities of men and affairs than they now get in two years of what are called "student apprentice courses" in the factories. In addition to all that, the young men who followed a well-administered plan of the type proposed by Mr. Alexander would have pursued their scientific and humanistic studies in the school with an appreciative understanding of the tremendous results that can be brought about through coöperative effort, and of the necessity of dependability and thoroughness in all important work, and also of the tremendous possibilities which exist for the use of the highest type of talent in the engineering industries. In these three important factors, which should lend an inspiration and a quickening of ambitions of the highest importance, our young men now graduating from engineering schools are commonly defective. It seems plain to me that the engineering schools must in some manner improve their processes if they are to make the men who will *go far* in the engineering industries of the future; and if they are to try an experiment, there is nothing which looks more likely to bring good results than this plan which is an analogue of the plan that has worked advantageously for the medical schools and the law schools.

I do not mean to suggest that it is necessary to have every engineering school close to a great manufacturing establishment in order that the improvements which are here in mind may be substantially brought about. An engineering school of fine grade close to a great manufacturing establishment which carries on a highly diversified business, and which is well organized, and which will deal with this sort of experiment in a sympathetic manner, will possess an advantage due to its position. But the schools that are isolated can work out their own shop and laboratory methods so as to bring very much of the same plan into effect; though it is my belief that no engineering school has yet approached the requirements, and also that an inspiration may be secured by the students' association with proper manufacturing establishments which cannot be obtained in the school shops.

C. A. Adams: Whatever prejudice or preconceived opinions one may have against this plan of coöperative engineering education, there are certain of the advantages claimed for it which are so desirable as to make one wish to see the experiment have a fair trial. Personally I am not yet ready to take a decided stand for or against the plan, although I incline to the opinion that its success will be much more limited than its promoters seem to anticipate.

The principal advantages which would accrue under the best conditions, in the order of their importance in my mind, are: first; social—the value of a fairly intimate association with large numbers of the so-called laboring class, the new point of view usually involved in such association; a consequent better preparation for the duties of citizenship; a better appreciation of the advantages of a college education, and more sympathy for those less fortunate: secondly; educational—the advantages under this head have been fully described by Mr. Alexander.

The principal disadvantages are: first, the numerous practical obstacles to the carrying out of any such plan, such as the difficulty in coördinating the college and shop work where there are several groups of men taking quite different college courses; the frequent change of residence; and the difficulty in finding suitable shops where the influences are such as to make possible the attainment of the advantages above described; secondly, the danger of over-emphasizing the commercial side of engineering. This I consider a very serious danger, although I realize that there are different opinions on this point.

A system adopted in Harvard University recently, follows pretty closely the suggestions made by Dr. Steinmetz. Each undergraduate registers in Harvard College, where his studies are almost wholly elective. If his preference be engineering, he is advised to lay a good broad foundation in science, mathematics and languages, and, where time permits, to take some general or cultural courses. Meantime he associates more or less with men studying in widely different fields and has every opportunity to determine whether or not his taste and ability lie in the direction of engineering, and if not, in what direction they do lie. After the completion of a certain number of courses, he receives the appropriate degree, A.B. or S.B. If the student still prefers engineering after graduation, he registers in the Graduate School of Applied Science where he completes his engineering studies in two or three years more, and receives the degree of master in electrical engineering or in the appropriate field. This school is thus a professional school similar to the law and medical schools. Its advantages over the old arrangement are: first, it insures a more mature choice of profession and eliminates many students wholly unfitted for engineering, but started in that direction by some one of the numerous chance elements; secondly, it encourages a more substantial foundation and a broader education; thirdly, it does not force each man through the same machine, but adapts the work to the wants of the individual. In short, it makes for a higher efficiency of education.

A. F. Ganz: If I correctly understand Mr. Alexander's coöperative plan, it is based on the principle that the student should learn some theory, then go into the factory and get some practice on that theory; on that basis he has planned a six year course, which is equivalent substantially to three years of factory work and three years of college work. Now all of us who have been teaching in technical schools know that our present four-year' course is already crowded, and this proposition would cut down our time for teaching theory from four years to three years. Mr. Alexander suggests that the time can be gained by cutting out shop work, a large part of laboratory work, and mechanical drawing. I do not believe that is possible. If the shop work, the laboratory work, and the mechanical-drawing work have been properly planned, —that is to give the student that information which he cannot get in practice—then I do not believe that the practical work in the factory can be made to take the place of the laboratory work and of the mechanical drawing. I believe that it is the main function of the laboratory to run parallel with the theoretical course in the class-room, and to give to the student practice, with his hands, of the theory which he has learned in the classroom.

I thoroughly believe in allowing the graduate from the technical school go into the shop and get practical experience; but three years of practical work mixed in with three years of theory is too large a proportion of practice. When we look through the usual curricula of our technical courses, we find in the first two years, largely, subjects like mathematics, physics, chemistry, and general cultural subjects. Now, surely, in the factory the student will get no practical experience which will help him in an understanding of any of these fundamental and very important subjects. It is only in the third year that we can begin to teach engineering work, and the best plan, it seems to me, for carrying out the suggestion of coöperative education, would be to let the student go out for one year during his college course, preferably between the third and fourth years, after he has had a good deal of theory. He should go into a large shop where a great variety of work is done, and not into a small shop, where only special machinery is built.

In regard to breaking into the theoretical work, several years ago Stevens Institute adopted a plan of having three terms, a first term of 14 weeks, then an intermediate term of 4 weeks, and then a third term of another 14 weeks. The object of the intermediate term was to give the student 4 weeks for solid practical work in laboratories, drawing room and shop. We have now abandoned this scheme for a number of reasons, one reason being that at the beginning of the third term we found that it took the student some time to get back to the theoretical work. I do not believe that this plan works nearly so well as the plan to make the theoretical work continuous and to put the practical work at the end; that is, in a summer term.

Chas. F. Scott: A good deal of our discussion of engineering education is, if we analyze it, really the consideration of a human slide-rule. We want a man to be capable of doing certain things. We consider, in a mechanical sort of way, that he should know how to do this, that, and the other thing, and we are apt to try to crowd into a curriculum more subjects than it is possible for the college course to cover adequately. But in the engineer it is not so much mere ability in mechanical calculations or manipulations that we care for, but some higher quality—a higher quality of mind, life in some higher terms, if the purpose of education is to translate life into its highest terms, the development of its consciousness, of its soul qualities, thinking and feeling, of its forces to direct conduct and control purpose. These indicate some of the things that we want in engineers as men; we want to develop men, and when we have the man it is a lesser question whether he is an engineer, or a doctor, or something else. We want the foundation for this larger usefulness; we want a man to get his life into the largest terms, by the development of himself as a man.

In engineering education, then, we want a general purpose and policy towards which to aim. The method of carrying it out is almost of secondary consequence. It cannot be the same method everywhere, and different methods, particularly in this period of evolution, are desirable. The new plan which is about to be carried out in Boston has its pros and cons. I think it is a most fortunate thing that an experiment of that kind, if we so choose to call it, can be tried. We need variety in methods as a means of gaining experience and as a tonic in our work. There is certainly one thing which will be gained by a method of that kind; it will give to the man the facility to adapt himself to conditions, to bring his theoretical and practical training to one side or the other, thus maintaining a just balance.

We separate too much the theoretical and the practical: they must go together hand in hand. I have in mind now some investigations Mr. Thomas carried on a few years ago, and it seemed to me his method was ideal. He would take his problem and study it, and work it out in mathematics, in x, y, and z, and come to a certain conclusion, and then undertake his test. He would get experimental results which gave him constants for his formula work, or which indicated some factor which had been omitted and which needed now to be included. He would then go back to the study of his formula, and integrate his new experience, which would give him a new hold when he came back to experiment.

One of the purposes in the apprentice courses as now conducted is that they change the point of view of the student. He has been in college, where he has been passive; he has been directed. Then when he goes out to the manufacturing company he feels that this is now his post-graduate course, and he waits for experience to be pushed into him, but he does not find the foreman running around with bits of experience to add to his information. He is at a loss for a time, and then finds he has to shift for himself; has to change from the passive to the active; for it is sink or swim. That is one of the best experiences of this apprenticeship course. Now, if in this Boston combination the school idea predominates, and the student is simply led around through the factory, and feels that everything there is simply for his benefit, and he fails to develop self-reliance, then something is going to be lost.

Gano Dunn: I have observed that the most effective graduate is the man who, somewhere in his college course has had a taste of practical experience, the man who has had at some time actually to earn his living. Contrary to the opinion of Mr. Alexander and of Professor D. C. Jackson, I think that the desirable contact with practical work cannot take the intimate form that they recommend. A college course should teach men what they cannot learn in after life. The very specialization of a college course contributes to learning some things more thoroughly than they can ever be learned when alternated with business activities. The subjects at college mutually support and illuminate one another. Intermittent college and practical work would, I fear, destroy this benefit.

The reason college graduates who have had practical experience are usually better than others, is not principally because of the things they have learned about technical subjects during the course of that experience, but because of what they have learned about life in general and the problems of discipline.

The *average* college student is not a man of much directive force. His tastes are not strong, and he is not very particular which way he goes. He needs polarization. If he can get it before he enters college or in the early part of his college career it will enormously increase the efficiency of his education. I attribute the greater effectiveness of the college graduate who has had experience to his early polarization in the field of life and his early submission to the discipline of the world.

From the manufacturer's point of view there are many obstacles to Mr. Alexander's scheme, even if there are none from the point of view of the educator. In surveying the field and taking note of the number and size of the electrical factories and the number and output of the electrical educational institutions, I think each manufacturer would be unable to take his quota of the electrical students. One very large manufacturing company might absorb all the students of one educational institution; a rough calculation indicates, however, that a proportional distribution of electrical students among electrical manufacturers would be more than the manufacturers could digest. The manufacturer holds on to even relatively low-grade employees, carrying them over dull times, remembering their loyalty and faithfulness in performing various operations. This asset, of greater value than most people realize, would be lost if workmen were changed once a week, once a month, or even once a quarter, whether these workmen were college students or not.

Without wishing to be taken too literally, it is a good thing for a student, somewhere in his college career, to " drill brass name-plates for six months " as in the case cited by Mr. Rushmore. It is a mental training. It corresponds to what a man gets in other countries in the army; and if while he is drilling brass name-plates the man is of the kind of selected material that Mr. Steinmetz would have the colleges accept, he will absorb, through having his eyes and ears open, a vast amount of knowledge about the organization of business, the democracy of relations between hands and foremen, the necessity of co-operation, and many other things that sooner or later he must surely learn.

I would add a word in most earnest support of the idea that we train only selected material at colleges. This is the true keynote to higher efficiency in education. It carries along with it, however, the obligation to employ only selected instructors. In many of our educational institutions we have as instructors men who however learned, do not possess the art of imparting their knowledge, who do not know how to make a lasting impression on the minds of their students, who do not appreciate what to emphasize and what to suppress; men who in the delivery of their lectures, for instance, do not have that touch of dramatic power that causes students in later life to look back to those lectures as the very foundations of their technical training. A high standard for instructor material must go hand in hand with a high standard for student material.

M. W. Alexander (by letter): The discussion of my paper indicates an impression on the part of some that my plan intends to supplant existing college engineering courses. A careful reading of the paper, however, would show that this is not the case. The underlying thought of the proposed plan is to provide an education especially adapted to the needs of prospective engineers who are to specialize in life along administrative and executive rather than purely engineering lines. These engineers must have an adequate practical as well as a thorough theoretical knowledge of engineering; and the best method to accomplish this, I believe, lies in an arrangement whereby the engineering education at college is aided and supplemented by a familiarity with the industrial methods of progressive manufacturing enterprises, which may best be gained through simultaneous participation in the practical work. The plan, moreover, aims to enlarge the college sphere through a course which, for reasons already outlined, would attract to it capable young men, who, through one cause or another, do not or cannot avail themselves of a college education under present conditions. Obviously, the proposed arrangement, if carried into effect, will in time react upon present engineering education by suggesting changes which will bring the regular engineering courses more fully into synchronism with the demands of modern industrial life.

Mr. Behrend agrees with me regarding the general proposition when he says that " a large number of electrical and mechanical engineers are needed in the manufacturing industries as foremen, superintendents, and master mechanics "; he does not, however, fully appreciate the value of a broad education for these men who, after all, occupy positions as foremen, master mechanics, and superintendents only as stepping stones to something higher. Inasmuch as they are to become eventually leaders of men and managers of enterprises, they should receive an adequate cultural development in addition to their scientific and practical training. Again Mr. Behrend is pleading for my proposition—although unintentionally perhaps—when he claims that the proposed plan is " like starting and stopping, accelerating and retarding the boy's mind continually instead of allowing him to obtain a given velocity and momentum." That is the very thing I am aiming at, namely, to make and keep the young man mentally so alert that he will be able to adjust himself quickly to varying conditions as they arise; he should not need a headway, so to speak, in order to be effective. The mind of the future manager must be trained to work like a polyphase motor, starting under load and quickly acquiring full speed, and not like the ordinary single-phase motor which must run under full speed before it can carry load.

Professor Norris falls into a similar error when he criticises the proposed plan on the score that there is loss of time in starting up after a change in work. It is one of the very objects of the plan to minimize this loss by offering frequent opportunities for practice in changing quickly from one line of activity to another; and this inability to make quick adjustments is a weakness which manufacturers see in recent college graduates. A manager has to change his work many times a day; one hour he is occupied with engineering problems, another hour with financial questions and perhaps the next hour with matters pertaining to the labor problem or the economics of production. Certainly, we should aim to train for such managerial capacity those students who will take up administrative work. This change from one class of work to another may of course be carried too far. It is for this reason that I do not advocate weekly changes such as are provided under the coöperative plan at the University of Cincinnati. I am advocating alternative periods of from six to ten weeks' duration, fully ample for the concentration of thought and work to which Mr. Behrend properly refers. The courses of study in technical colleges will bear me out in this respect, for many of their subjects are completely covered during a similar period of time.

Again, I note with pleasure Mr. Behrend's support of my contention that a correlated practical and theoretical engineering education during the so-called college career will prove very beneficial for engineers who wish to engage in manufacturing business or to become executive officers of industrial establishments and public service corporations, for he says: " If we set aside certain colleges of ours for the purpose of giving a practical education to the class of men who are not likely to be concerned in later life with the difficult and complex questions of engineering, I can see no objection to adopting a coöperative course in these technical schools."

Assuming all the time that we are dealing with recognized engineering colleges which confer the usual degrees upon their graduates, it must be admitted that whether such courses are to be given in separate colleges or side by side with regular courses in the same college is, after all, a matter of detail. Local conditions will have to be taken into account, and it is by no means necessary to have these coöperative courses introduced in all engineering colleges. Naturally they would be established, in such colleges as are located near the large manufacturing industries, and they could prove their value in these particular instances, even though other colleges may not be able to offer the same opportunity. This argument against the proposed plan, put forth by Mr. Behrend, would hold just as good in advising Harvard University not to start its graduate school of business and commerce because other colleges are not in a position to do the same. Furthermore, inasmuch as I am advocating alternating periods of from six to ten weeks, and not of one week's duration, as Mr. Behrend erroneously seems to have in mind, it would be feasible for colleges and manufacturing companies to establish a coöperative course even though they should be separated by a distance of fifty or one hundred miles.

The coöperative course can only be open to a comparatively few, at the most, taking the factory side of the question into account; and it is therefore intended for those especially fitted for the work for which the course aims to train. While I, therefore, fully agree with Professor Norris that elementary education must be laid out for the average boy, I differ from him with regard to higher education in believing that the latter and especially the one of a technological character should differentiate and concern itself with the various capacities of the students so as to allow each, within reasonable limits, a full and free development. A young man should not go into an engineering college unless he is well fitted for an engineering career. Dr. Steinmetz is right in advocating measures by which the engineering college will eliminate the mediocre and develop only the well-qualified student. The latter should be taught the humanities as well as the sciences, and I am ready to go with Professor Norris as far in this respect as he wishes, for I plead for a broad educational training at all engineering colleges, so that the man as well as the engineer will be developed. Professor Norris' fear that students may lose the sense of responsibility for a task when they know that the task is to be dropped at a certain time whether completed or not, would disappear under proper training. To me this danger appeals with much less force than that concerning the lack of serious responsibility of our present college students, who, for four years, enjoy a delightful college freedom without any restraining influence such as intermittent discipline of practical life would bring. I should not want to deprive young men of this college freedom with all its great value, but I should wish to give it greater significance by giving it a background such as the factory discipline would furnish. The ideal of the college linked to the real of the factory is bound to be wholesome in its effect upon the character and stamina of the young men, who, under such conditions, will be developed, rather than injured by the awakening of a keen interest in commercial work, such as Mr. Thomas seems to fear. Experience, furthermore, refutes his contention, for those who during vacations engage in some gainful occupation, even though not at all related to the science of engineering, usually turn out to be good engineers. These students feel the inspiration of practical work, and through it, see clearer the value of a theoretical education.

The statement of Professor Brooks that high school graduates as a rule are entirely too young to do satisfactory work in a manufacturing establishment is surprising to me; if it were true it would be a serious indictment of our trade apprenticeship systems, under which grammar school graduates are required to do commercial work in factories, which they have been entirely able to perform without any inujry to their physical development. It goes without saying, of course, that the work in the factory must be suited to the physical maturity of the young man just as much as the theoretical work in college must be suited to his mental maturity. It must also be borne in mind that thousands of young men with a complete or partial high school education enter our factories and workshops and grow up into healthy and efficient men. Would not a periodical rest from the physical work with a corresponding period of mental activity develop these young men better physically as well as mentally? The elective system under the proposed plan would have to be practically eliminated, as Professor Brooks points out, but this is no objection to the plan. The elective system, however, even though our foremost educational thinker, President Eliot, fathers and favors it, is by no means regarded as the only method of securing an effective college training. The coöperative engineering course, aiming to train young men for a definite career, is an application of the elective system in the broadest sense of the term, for the student elects specific subjects which he must pursue in order to complete the requirements for a degree. The makers of such a course must lay it out on the broad basis of cultural as well as scientific instruction.

Some of the speakers have questioned the advisability of cutting the shop work out of the college curriculum. I think, we will all agree that so far as the term "shop work" at college refers to the teaching of the mechanical principles involved in machine work, the college should still attend to this part of education. The familiarity with machine processes, however, inasmuch as it is based on a more or less extended practice, could be left to the factory under the proposed plan, where it can be taught more effectively, inasmuch as it is taught by practical men and under real industrial conditions. In the proposed plan provision is made for the college to go much further in the educational phase of shop work by giving a more thorough and extended course in shapes of tools, cutting speeds and feeds, and similar important questions, than is done at the present time. Whether the college professor gives a course in these latter subjects at college or at the factory, or whether a practical man is selected as special instructor in these subjects, is, after all, only a detail in the whole plan. Similar arguments would apply to the part which the college and the manufacturing company ought to play in the teaching of mechanical drawing.

Considering the whole matter in this light, and studying carefully a detailed course of both the theoretical and practical studies under the proposed plan, Professor Ganz's criticism that a four-years' theoretical training is to be crowded into a three-years' period falls to the ground; for it will be seen that under the proposed plan as many, and even more weeks, are devoted to the college studies than are provided for at present in most leading technological colleges for the same subjects. As a matter of fact, the concrete plan which I have worked out provides for one hundred and thirty-two weeks at college, one hundred and forty-one weeks at the factory and thirty-five weeks for vacation, or a total of three hundred and eight weeks for the period beginning with the middle of July after high school graduation, and ending with the middle of June six years later. The particular college which I have in mind, devotes only one hundred and twenty weeks to corresponding studies during a four-years course. The extra time in the proposed plan is gained by a trial period of two months of practical work previous to the college work, and by a shortening of the present, I believe all-too-long summer vacation periods from sixteen to five weeks each. Furthermore, I firmly believe that coördinate theoretical and practical work as proposed will make it possible to cover more ground at college in a given time than can be done under the present system. A knowledge of practical work will materially help the student in a quick understanding of most of the engineering subjects taught at college.

In closing, I wish to emphasize again, that the proposed plan aims to train high grade manufacturing and executive engineers who may receive their college degree on the basis of a thorough engineering education, and besides have obtained an adequate practical training with special reference to their future usefulness.

Application of any theory, after all, will prove whether or not the theory is correct. Thus a trial of the plan which I have proposed will prove if it is efficacious; and I am glad to find so many members of the American Institute of Electrical Engineers ready to see a sufficient value in the proposed coöperative course to hope for a fair trial where conditions permit.

DISCUSSION ON " VOLTAGE RATIO IN SYNCHRONOUS CONVERTERS, WITH SPECIAL REFERENCE TO THE SPLIT-POLE CONVERTER " AND ON " APPLICATION OF STORAGE-BATTERIES TO REGULATION OF ALTERNATING-CURRENT SYSTEMS."

ATLANTIC CITY, N. J., JULY 1, 1908.

(Subject to final revision for the Transactions.)

P. M. Lincoln: These papers give a much clearer insight into the theory and expected performance of the so-called " split-pole " synchronous converter than anything which has been produced up to date. With these papers before him, the engineer who contemplates using this type of machine is in much better position to judge of its merits than ever before.

In both papers, almost the only question discussed, so far as the split-pole synchronous converter is concerned, is that of wave form. Although of prime importance, this question of wave form is by no means the only one which is to determine whether this type of construction will stand the test of time, or whether, on the other hand, it will find its way into the oblivion of the monocyclic system, and other disappointed hopes. This split-pole method of obtaining a variable voltage must be compared with other methods of obtaining the same results, not only with respect to wave form, but also with respect to relative capacity, cost, efficiency, commutation, power factor, weight, floor space, heating, reliability, noise, possibility of resonance, rapidity of voltage change, liability of hunting, etc. It is only the test of time that can prove out this machine. Some light, however, can be thrown on the matter by further discussion of some of the questions mentioned above.

Wave form. In my discussion of this machine before the Institute in February, the following statement occurs:

> With a field form other than a sine, the wave form across the electrical diameter deviates from sine form less than that across any chord.

While this statement is perfectly true for the general case, I wish to take this opportunity to acknowledge that it does not apply to the case of the synchronous converter as ordinarily constructed. As Professor Adams has pointed out, harmonics of any one order can be eliminated from the electromotive-force wave of a synchronous converter by suitably choosing the angle between adjacent taps. For instance, in a converter in which the adjacent taps are spaced at an angle of $\frac{2\pi}{3}$, or 120 deg., third harmonics will be eliminated. With adjacent taps spaced at an angle of $\frac{2\pi}{5}$, or 72 deg., fifth harmonics will be eliminated With taps $\frac{2\pi}{7}$, or 51.4 deg. apart, seventh harmonics will be eliminated, etc.

In the above not only are the third, fifth and seventh harmonics eliminated from the electromotive-force wave, but also in each case multiples of these harmonics are eliminated. Likewise, with taps spaced apart by an angle of $\frac{2\pi}{2}$, or 180 deg., all second harmonics are eliminated and multiples thereof; in other words, all even harmonics. With taps $\frac{2\pi}{4}$, or 90 deg. apart all fourth harmonics and multiples thereof are eliminated, etc. Professor Adams has pointed out that in general, harmonics enter into a wave form in values in inverse proportion to their order; that is, ordinarily the third harmonic will be of greater value than the fifth, the fifth of greater value than the seventh, etc.

In the most general case, that is, where even harmonics enter as well as odd, the same relation will hold. In general, the second harmonic will be of greater value than the third, the third greater than the fourth, etc. It follows, therefore, that in this general case the 180-deg. taps will give rise to a wave form which deviates from a sine to the minimum extent, since it eliminates all even harmonics.

It must be borne in mind, however, that so long as the negative and positive fluxes in a synchronous converter, or other electrical machine, are of the same shape, even harmonics are eliminated due to this fact. We can, therefore, entirely neglect the matter of even harmonics in selecting angular distance between taps in synchronous converters, and can make the selection such that the maximum of odd harmonics will disappear. From the above it is evident that the connection which will eliminate third harmonics and multiples thereof will give rise to the wave form which deviates the least from the sine wave. It is evident, therefore, that in a synchronous converter or other electrical machine in which the positive and negative field forms are of the same shape, the 120-degree taps, not the 180-degree, will give a wave form which deviates a minimum amount from a sine.

In a split-pole synchronous converter, therefore, the secret of obtaining a variable voltage by variation of the field form, and at the same time a wave form fairly free from harmonics, is: first, to use a three-phase converter; secondly to design the field form so that it is composed as far as possible of nothing but a fundamental form upon which is superposed a variable third-harmonic form. It is evident that a constancy of wave form can be realized in a three-phase synchronous converter only as we approach the condition that the superposed variable-field form contains nothing but third harmonics or multiples thereof. Further consideration will show that in the three-part pole converter it is not difficult to obtain a close approximation to this condition.

This fact is quite readily shown by an inspection of Figs 9, 11 and 13 of Mr. Woodbridge's paper. An inspection of these figures shows that by far the larger part of the field distortion takes the form of a superposed third harmonic. In Fig. 9 this superposed third is about 33 per cent. of the maximum field value, in Fig. 11 about 54 per cent., and in Fig. 13 the third is practically absent. During this field variation the total voltage variation is about 19 per cent., thus proving out in a beautiful manner the theoretical curve shown by Professor Adams in Fig. 6. Since these third harmonic variations in the field form do not affect the 120-degree electromotive-force wave, comparatively slight changes in the resulting wave form may be expected, as shown by Figs. 10, 12 and 14.

With a two-part pole the problem of eliminating the higher harmonics is not so simple. Refer, for instance, to Fig. 7, of Professor Adams' paper. The typical two-part field form shown therein gives a rather large third, but inspection also shows that with such a two-part field form it is impossible to confine the variations to thirds exclusively as is the case in the three-part pole machine. In order to have practically nothing but the third harmonic enter, it would be necessary to have a downward projecting lobe on the left-hand side of this field form as well as on the right-hand side as shown. Since it is impossible to confine the field-form variations to thirds it follows that the wave-form variations will be much greater in the two-part pole synchronous converter than in the three-part.

Mr. Woodbridge suggests an ingenious scheme in Fig. 18, for further reducing the effects of the fifth and seventh harmonics in the case of a two-part pole synchronous converter. He, however, suggests a rather serious objection to the scheme, in noting that the loss in a single bar of a converter so connected is 50 per cent. higher than the average loss. That the average per slot is not so high will assist matters inside the slot, but it is well known that heavily loaded windings suffer from heating at points outside, not inside the slots. This objection becomes still more important when we consider that the single-bar loss becomes still more than 50 per cent. above the average with power factors other than 100 per cent.

I might note, in passing, that in order to arrive at the true electromotive-force curves both Figs. 20 and 21 of Mr. Woodbridge's paper should have a large third harmonic added, the values of which should be nearly 20 per cent. in Fig. 20 and nearly 10 per cent. in Fig. 21. While these third harmonics do not appear in the external three-phase circuit, they do cause transformers placed across the diameter (Fig. 20) and the 82 per cent. chord (Fig. 21) to pass through a magnetizing cycle which will increase their iron losses in the approximate ratio of the entering third; that is, 20 per cent. increase for Fig. 20 and 10 per cent. increase for Fig. 21.

A class of service from which this type of synchronous converter is effectually barred is in Edison three-wire circuits in which the neutral is brought out from the transformers and connected to the neutral of the lighting system; as any attempt to use the machine in this service would superpose the third harmonic upon the direct-current circuits, and also cause circulating currents in the transformer windings if more than one transformer were tapped into the neutral.

In general, so far as wave form is concerned, it seems possible so to design the three-part synchronous converter pole that no appreciable circulating current will be caused in the outside circuits on account of wave-form variation, provided three-phase converters are used. In the case of the two-part pole, the circulating currents caused by variable wave form will probably be appreciable but not disastrous, unless very large alternating and direct current voltage variations be attempted.

Capacities and costs. In order to obtain the variable voltage feature of the split-pole converter, it is necessary to make a considerable sacrifice in the output that can be obtained from a given amount of material. This can best be shown by reference to Figs. 11 and 13 of Mr. Woodbridge's paper. Fig. 11, for instance, shows the resulting field form of one of these split-pole converters when it is delivering its maximum voltage. The deep notch out of the middle of the field form in Fig. 11 as measured by a planimeter amounts to about 33 per cent. of the area under the curve. In other words, if the notch were absent and the converter armature winding suitably changed, an increase in capacity could be obtained from the same converter of some 25 per cent. without increasing its cost of the rotary over one designed with a field form like Fig. 11. This means that a sacrifice of 33 per cent. in capacity must be made in order to obtain the variable voltage feature. Coupled with its other disadvantages, this is probably enough to eliminate the three-part-pole converter from any active competition with other modes of obtaining variable voltage.

Referring to Fig. 13, the same criticism applies, although in this case it is not of so much importance as this Fig. shows the minimum voltage condition and not the maximum voltage as indicated in Fig. 11. The converter with a field form as in Fig. 13 suffers a loss in capacity of about 25 per cent. as compared with a converter of normal field form, the material of the teeth therein being worked to the same magnetic density in both cases.

Referring to the two-part pole scheme, the same criticism applies, but the capacities do not suffer quite so large a decrease. For instance the arrangement shown by Mr. Woodbridge in Fig. 17, shows a notch between the main and auxiliary poles of 20 per cent. of the available pole width. This would have the effect of decreasing the capacity of such a machine in approximately the same ratio. Another criticism of the arrangement shown in Fig. 17 is that the notch in which the brushes rest is given a width of only 30 degrees or 16⅔ per cent. of the pitch. Experience indicates that this width is too narrow for good commutating conditions. A width of 20 to 25 per cent.

should be allowed for the inter-polar space even in a converter of normal design, and this split-pole type should have a still wider neutral. Taking this into consideration, a still further decrease in capacity will result unless the designer is willing to take considerable risk with the commutation.

While it is probable that Mr. Woodbridge's suggested pole arrangement of Fig. 17 can be considerably bettered so far as capacity is concerned, the output that can be obtained from a given amount of material will always be much less in a split-pole converter than in one of normal design. The cost of obtaining a given voltage variation by this means is at best probably as great or greater than that of obtaining the same effect in other ways.

Efficiency and heating. In addition to the split-pole converter requiring considerably more active iron in its armature, this iron is carried through a flux cycle which introduces much greater losses than in the case of a converter of normal design. For instance, in Fig. 11, of Mr. Woodbridge's paper, the introduction of the notch in the field form not only increases the amount of iron in the teeth by about 33 per cent. but also increases the losses that take place in this iron by about 15 per cent. The total iron losses including the body of the armature as well as the teeth at the maximum voltage are increased by about 35 per cent. to 50 per cent. over those of a normal design.

With a two-part pole design as shown in Fig. 17, of Mr. Woodbridge's paper, the iron losses will be increased about 15 per cent. at maximum voltage and about 35 per cent. at minimum voltage. This coupled with the fact that this design requires about 20 per cent. additional material increases the total iron losses in such a machine from 40 per cent. to 60 per cent. The field copper losses will be increased on account of the doubled or trebled number of fields to be magnetized. Armature copper loss be increased, first, because the machine will be larger and, secondly, because of the circulation of the higher harmonic currents.

It is evident that the best efficiencies that can be obtained from such a machine will be as low and probably lower than the alternative method of obtaining voltage variation—by means of a separate synchronous booster mounted on the same shaft as a normally designed converter.

Commutation. So far as commutation is concerned, the design of the three-part pole machine should not introduce any particular difficulties or problems, provided the notch between the poles is not made too small. The field strengths adjacent to the brushes although variable are always equal and opposite, so that the point at which commutation takes place is not subjected to a variable field. This cannot be said of the two-part pole machine, refer to Fig. 17, for instance, of Mr. Woodbridge's paper, and note that the brushes are set at points *A* and *D*. The small field M. P. is assumed to vary from a magnitude equal to field G. H. in the positive direction to the same magnitude in the negative direction. As this variation occurs it is very evident that the field strength at the points *A* and *D* must vary, since at the one extreme the adjacent fields are equal and opposite, and at the other, equal and the same. If, therefore, proper commutating conditions are secured at one extreme, it will be necessary to sacrifice commutating conditions at the other extreme. It is true that the field at the point of commutation can be made to act in a direction to assist commutation. But it is impossible to take advantage of this feature since in this case we would have a condition very similar to a commutating pole generator the strength of whose commutating pole varies from full value to zero, depending upon conditions totally independent of the current to be commutated. It is evident that under these conditions the field at the commutating point is a hindrance not a help to commutation.

Resonance. In long-distance transmission systems, or systems wherein considerable amounts of high-tension cable are used, there is of course, always a considerable amount of capacity. This capacity, coupled with the reactance of transformers presents the possibility of resonance being set up therein. Although the three-phase connection of a split-pole converter eliminates the third harmonic and all multiples thereof, Professor Adams has shown that all other harmonics appear in the system to exactly the same extent in the 120-degree electromotive-force wave as in the 180-degree wave.

It is evident, therefore, that such a machine even connected three-phase will impress harmonics upon the outside circuits, which will vary both in order and in magnitude. That at some point in the voltage range a condition of resonance will occur is certainly not without the bounds of possibility. This is particularly true with the two-part-pole converter, since, as pointed out above, it is impossible with this type to eliminate the higher harmonics.

Noise. All of the causes for noisy electrical machines are not known. Some of them, however, have been determined and one of the most important is the sudden transition of armature teeth from one magnetic density to another. The fact that a relatively small number of armature teeth are at a given magnetic density at once is another contributing cause. Evidently both of these causes enter to make the design of a noiseless split-pole converter difficult, whether it be of the three-part- or the two-part-pole type. In order to obtain a design to give noiseless operation, it may often be necessary to make a considerable additional sacrifice in capacity.

Rapidity of voltage change. In the application of storage batteries to what Mr. Woodbridge calls the "regulation" of alternating current systems, or, in other words, to assuming load fluctuations that would otherwise fall on the generating plant, ability to change the voltage of a rotary rapidly is highly essential, since rapidity in voltage change means rapidity on the part of the storage battery in assuming the fluctuations of load.

In order to change the voltage of either a split-pole converter or of a normal converter equipped with a separate synchronous booster (similar to Fig. 5, Mr. Woodbridge's paper) it is necessary to cause a certain amount of change in the field flux in the first case of the main converter poles and in the second case of the booster poles. Professor Adams has pointed out that the amount of field flux necessary to produce a given voltage change in the split-pole machine is approximately in proportion to the harmonic introduced into the converter in order to produce that voltage change. Thus the total flux change necessary to produce a given voltage change is three times greater when that voltage change is caused by superposing a third harmonic than if caused by changing the fundamental, five times greater if caused by a fifth harmonic, etc. The creation, or the changing, of location of magnetic fluxes requires energy in proportion to the volume of flux created or changed. With a given force acting to produce flux changes it is evident, therefore, that the rapidity of voltage change is at least three times as great when acting upon the fundamental frequency (as is the case in a converter with synchronous booster) than when acting through the agency of a third or higher harmonic (as is the case with the split-pole converter). In this particular, therefore, the split-pole converter is at considerable disadvantage when compared with the alternative of a normal converter equipped with a synchronous booster.

Another important advantage accruing to the separate booster arrangement in point of rapidity of voltage change, is that the flux upon which the regulator must operate in order to change voltage the booster field may be left unhampered with dampers. In order to insure proper operation, the main rotary fields, no matter whether split pole or otherwise, should be equipped with relatively heavy dampers.

In the case of the split-pole machine the regulator, of whatever kind, must cause magnetic fluxes to change their positions and magnitudes in spite of the enveloping damper. In the separate booster machine the omission of dampers from the booster fields, while it does not interfere with the running characteristics, gives the regulator an opportunity of operating upon a magnetic flux not enveloped by a damper, and this gives a much higher rapidity of action. Just how much this point will affect the relative speed of voltage changes is problematical, but it is probable that this effect will be still greater than the one mentioned in the preceding paragraph, thus placing the separate booster machine in an entirely different class so far as the rapidity of voltage change is concerned.

It is on this score of rapidity of action that Mr. Woodbridge bases an argument for the converter as against the motor-generator. He points out that in the motor-generator set there is a lag between the time when the battery begins to discharge the direct current machine and the time this energy begins to appear in the alternating current circuit, owing to the fact that the "lost motion", so to speak, in the motor-generator set must be taken up. While this time lag is theoretically present it hardly deserves the term "appreciable" applied to it by Mr. Woodbridge. I have considered a number of typical motor-generator sets and find that the time lag mentioned by Mr. Woodbridge is of the order of 0.001 seconds. Compared to the time required by mechanical movement on the part of a regulator and the time required for field flux changes, the above time lag is zero. I agree with Mr. Woodbridge's conclusion that a converter is preferable to a motor generator for the purpose described, but my conclusion is not arrived at by the same process of reasoning.

In conclusion, it is my opinion, for reasons set forth above, that the split-pole converter has disadvantages that far outweigh its advantages, when compared with the alternate, a normally developed converter with a sycnhronous booster of the same number of poles, mounted on the same shaft.

A. S. Hubbard: The paper by Mr. Woodbridge is interesting as outlining some of the methods for compelling and controlling storage-battery charge and discharge to steady the load on alternating-current generators. These methods must necessarily be mainly suggested and prospective, because so far as I am informed there have been installed in this country but five storage-battery plants for the regulation of alternating-current loads. One of these five plants, however, is not now in operation as an alternating current regulating plant, but was installed for the purpose of controlling the output from two generators at different voltages, tied together and to the transmission lines by transformers. Two current coils, each taking current from one of the generators, actuated a single carbon regulator which controlled a direct current booster in the battery circuit. The regulation of this plant was very erratic being only within about 33 per cent; that is, the load on the generators varies from 33 per cent above to 33 per cent below the average.

The single phase plant, mentioned by Mr. Woodbridge although included in the five, cannot be taken as a fair example of alternating current load regulation, except for isolated, special cases, such as the plant of the Spokane and Inland Railway, where frequency or phase-changing is necessary. The regulation of this plant is effected by a single coil regulator actuated by current variations. As this coil is installed in the circuit leading to the induction motor, its current will be proportional to the current supplied to the motor, which current is affected by the line voltage, load, and frequency. Though I believe this plant to be successful, owing to peculiar local conditions, I think Mr. Woodbridge will agree that in general, definite, close regulation cannot be obtained with current regulation, except where there are no power-factor changes, or where the power-factor changes with load in a definite way; that is to say, that successful current regulation has been and will be the exception rather than the rule. That certainly is the conclusion I came to after considerable experimenting, as a result of which I devised and put in operation regulation by current times power-factor in a plant, where regulation by current alone had been a failure.

The third plant includes a two coil regulator, of the dynamometer type. With this type of regulator the battery may be compelled to charge and discharge in response to variations of the true energy; that is, account can be taken of current, voltage, and power-factor variations. I have no information as to the completion of this plant, but the regulation obtained some months ago was but 25 per cent; that is, the watt load varied from 25 per cent below to 25 per cent above the average, with considerably smaller charges and discharges than the size of battery would seem to warrant. As a carbon regulator with the usual retarding spring is used at this plant the lower the average load the worse the regulation.

The fourth plant has been in operation for something over two years, and except for slight delays due to the grounding of the series transformers on two occasions by lightning, has been operating continuously since that time. Water power is here used to generate 13,200-volt, three-phase, 25-cycle alternating current. This is all transmitted approximately five miles to a sub-station, where a portion of the power is transformed and converted and used for direct current railway work and alternating current lighting. The rest of the power is used at other sub-stations, one being located 12 miles away. The common sub-station contains two converters, 150 kw. each, a frequency changer, and a 280-cell, 400-ampere, one-hour battery, with its booster and regulating apparatus. The regulation at this plant is in accordance with variations of amperes times power-factor and is accomplished as follows:

In the incoming high-tension lines, three current transformers are installed, with their secondaries connected to a second set of three current transformers located back of the switchboard and provided with sectional secondaries connected to a compensator head. From the compensator head, the current is led to the collector rings of the rectifier. The rectifier consists of a number of discs of armature steel perforated near their edges and mounted on a shaft. A bipolar winding is threaded through the holes and connected at one end at points 120 degrees apart to the collector rings and at the other end to a commutator. The rectifier is connected to and driven by a bipolar synchronous motor built with special reference to minimum hunting.

The alternating currents from the series transformers produce a rotary field in the rectifier, which latter is mechanically rotated at the same speed but in the opposite direction by the synchronous motor. As the synchronous motor armature turns in synchronism with the voltage of the system, and the rotary field in synchronism with the current, there is produced in space a field whose position is stationary so long as the power-factor remains unchanged. A change in current without a change in power-factor merely increases the magnitude of the field, but does not change its position.

A single pair of brushes, *a*, arranged diametrically opposite and bearing on the commutator at points of maximum voltage, when the power generated is at 100 per cent power factor, will give a direct current which will vary in accordance with variations of the alternating current transmitted, independent of change of power-factor within very wide limits, because the current transformers feeding the rectifier tend to preserve their current transformation ratio irrespective of changes in resistance of their secondary circuits. And while the position of the field changes, the voltage on the commutator of the rectifier also changes and rises until of sufficient value to deliver a direct current over the circuit connecting the *a* brushes equal to the transformation ratio value of the current transformers. When, however, as is the case at the plant in question, a second set of brushes, *b*, is used on the commutator at 90 electrical degrees from the others and connected to a circuit having resistance and inductance characteristics corresponding to the characteristics of the circuit connected to the other brushes, a by-pass is provided and two direct currents are obtained, one of which, *a′*, varies as the energy current component and the other, *b′* as the wattless current component of the current in the alternating current line. *a′* is used to regulate the battery charge and discharge, and *b′* can be used to correct the power-factor by changing the excitation of a synchronous motor or a synchronous converter. The direction of *b′* is in one direction for lead and in the other direction for lag. The watt regulation at this plant is 3.5 per cent; that is, the kilowatt load on the generators varies only 3.5 per cent from any average.

The load regulation is so good that the voltage is constant, and the Tirrell regulator formerly used at the power house has been taken out and used on the lighting circuit supplied from the induction-motor driven frequency-changer. The 3.5 per cent regulation is obtained with battery charges up to the one hour rate and with discharges of two and one half times the one-hour rate and with booster voltages up to 140 volts.

The sectional series transformers and the compensator head are provided to enable the energy load to be changed at will, during operation, from about 50 kw. to 1000 kw. The regulation is 3.5 per cent. of any value between these limits.

Safety devices are provided so that if the synchronous motor goes out of step, or a short-circuit comes on the lines, the series transformers are automatically short-circuited and the regulation "killed."

It will be noted that variations of output from this rectifier do not affect the load on the synchronous motor driving it, nor has the rectifier any motor action, both very important points.

The fifth plant is a 60-cycle, 2300-volt, three-phase system, a turbine being used ordinarily for the generation of power. The regulating equipment of this plant is of the same type as that previously described, except that the apparatus is designed for 60 cycles. The rectifier and its synchronous motor have six poles, and but one series transformer is used in one phase. The regulation obtained here is 4 per cent of any average, the usual average being 800 kw. The variation is but 32 kw. In this plant also, the load is kept so steady that it is not necessary to operate the Tirrell regulator for voltage regulation, even though a portion of the output is used for lighting. This plant has been in operation for about 6 months.

While the multiplying features mentioned by Mr. Woodbridge are present in the rectifiers of the fourth and fifth plants here described, as well as in that described by him, this multiplication is not due so much to any shift of field or current in the by-pass circuit as it is to an inherent characteristic of the rectifier fed by series transformers, and can be made of any desired value within wide limits by proper design. The direct-current output from these rectifiers is about 40 watts (10 volts and 4 amperes) the direct current from the *a* brushes varying from about 2.75 amperes to about 5.5 amperes for an energy change on the line of only 3.5 per cent plus or minus. By changing the relation between the characteristics of the *a* and *b* circuits, various effects and any desired combination of currents and of energy regulation can be obtained. But one of these rectifiers is required for both load regulation and power-factor correction, the *a* circuit controlling the load regulation, and the *b* circuit the power-factor.

The dynamometer control is an electromechanical device that has pronounced to inertia; in my opinion it is not so good as the rectifier control of plants with water wheels, steam turbines, or gas engines as prime movers.

The question as to what type of apparatus to use for the connecting link for the transfer of energy between the alternating current and the direct current circuits, is one in which enters the efficiency of the apparatus and the magnitude and direction of the loads to be transferred. If an alternating current booster is used, in most cases this belongs to the high-tension side.

The split-pole converter is undoubtedly a distinct contribution to alternating-current distribution, although the changing shape of the voltage wave of this machine as its alternating current-direct current ratio is changed, may seriously affect the operation of the small synchronous motor proposed for driving the rectifier at the Gary plant. My experience is, that to insure stability and absence of hunting in a synchronous motor, the wave shape of this motor must correspond to the wave shape of the nearest preponderating synchronous machine.

W. L. Waters: Messrs. Adams and Woodbridge have worked out in an interesting way the mathematical theory of the split-pole converter. In working out any such problem mathematically it is necessary to make a number of assumptions in order to simplify the problem. Both Messrs. Adams and Woodbridge show that it is mathematically possible by means of a split-pole converter to obtain a considerable voltage variation without introducing serious distortion of wave form, or any great number of higher harmonics into the wave form of the converter. It is then simply a question whether these mathematical deductions are borne out in practice.

The statement that any particular harmonic can be entirely eliminated by suitably choosing the angle between the various taps on the armature and the pitch of the winding may be mathematically correct, but I doubt very much whether this will be found true in practice. The fact that the poles are not all exactly equal is neglected, and that consequently there are local circulating currents in any multiple-circuit converter armature. Also, the fact that there is a certain amount of electrostatic capacity between different parts of the armature winding and the frame which causes local higher harmonics circulating currents and a tendency for the higher harmonics to reappear in the voltage wave form. There are a number of similar assumptions that are necessarily made in any mathematical treatment, but it is a matter of actual experience as to the extent to which they will modify the wave form obtained under actual operating conditions and under the special conditions which at times occur in an operating power circuit.

Mr. Lincoln has cited a number of instances in which this split-pole is inferior to the standard converter: its increased size; increased core loss; increased field copper loss; increased armature heating, due to the fact that the alternating and direct currents do not properly neutralize each other with the varying voltage ratio; and also that on such a converter provided with dampers the voltage control will be extremely slow-acting compared with the standard alternating- or direct-current booster. I think, however, that Mr. Lincoln has not sufficiently emphasized the comparatively poor commutation of these converters under general operating conditions of the power circuit.

If there is any disturbance on the system causing hunting and sudden change in voltage or speed of the converter, there will be local equalizing currents flowing through the armature conductors, and the rotating field of the armature will fluctuate rapidly both in magnitude and in position. Similar fluctuating fields will be induced by currents in the dampers in the pole faces, with the result that the distribution of magnetism on the pole face will fluctuate and in consequence the voltage ratio and the terminal voltage will fluctuate. This will make the loads on the converter and its voltage and current fluctuate, and will greatly increase the tendency of the machine to hunt. If the converter is running in parallel with a battery, this fluctuation in voltage would probably be disastrous. It is also practically certain that unless such a converter is designed with extremely large interpolar gap and neutral point (thus necessitating a large machine) it will be very much more sensitive in regard to commutation than the standard converter, this sensitiveness being due to the inequalities in the distribution of magnetism at the pole tips and to the fact that this distribution varies from time to time.

It is not easy to see the advantages to be gained by the adoption of this split-pole converter over a standard alternating- or direct-current booster. Such a booster combination is much more flexible, quicker acting, and introduces no distortion or circulating currents into the system. The most that can be said for the split-pole converter is that it may possibly work out a little cheaper in certain cases, but to offset this there is the introduction of higher harmonics into the system and the probability of commutation troubles and greater liabilities of hunting. The split-pole converter at the present time can only be considered as a theoretical proposition. The fact that it operates well on the test floor and shows up satisfactorily under favorable conditions cannot be taken as indicating its suitability for general work. Before it is finally accepted, we must have the experience of two or three years' in practical operation on a power system, subject to all the sudden variations and fluctuations that take place in such a system.

Charles P. Steinmetz: The synchronous converter has been with us now in commercial use for 15 years, and has always been considered as an apparatus giving a constant ratio of conversion. It is very remarkable, then, that in the last few years we should have found out that this ratio can be varied over a wide range. To some extent it is rather discouraging to the engineer, to find in such a well known apparatus a feature which he never thought of before. At the same time it is encouraging to think that even in such familiar apparatus there may be a good many latent valuable properties.

Though I have nothing to add to the subject-matter of the two papers, I would like to explain the method of operation in a slightly different manner, to show, without the use of mathematics, how the converter operates in giving a variable ratio, and thereby incidentally, I believe, also explain some misconceptions in Mr. Lincoln's criticism regarding commutation, output, and heating.

In a synchronous converter, with a sine wave of alternating voltage, and the commutator brushes set at the magnetic neutral; that is, at right angles to the resultant magnetic flux, the direct voltage is constant at constant impressed alternating voltage. It equals the maximum value of the alternating voltage between two diametrically opposite points of the commutator, or " diametrical voltage ", and the diametrical voltage is twice the voltage between alternating lead and neutral, or star voltage of the polyphase system.

A change of the direct voltage at constant impressed alternating voltage can be produced:

1. Either by changing the position angle between the commutator brushes and the resultant magnetic flux, so that the direct voltage between the brushes is not the maximum diametrical alternating voltage, but only a part thereof.

2. Or by changing the maximum diametrical alternating voltage at constant effective impressed voltage, by wave shape distortion by the superposition of higher harmonics.

In the former case, only a reduction of the direct voltage below the normal value can be produced; in the latter case, an increase as well as a reduction can be produced. An increase can be produced if the higher harmonics are in phase; and a reduction, if the higher harmonics are in opposition to the fundamental wave of the diametrical or star voltage.

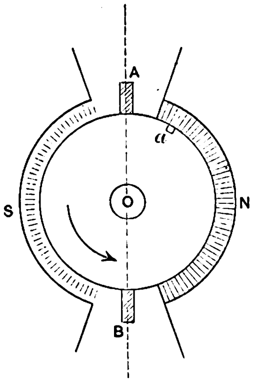


Fig.1

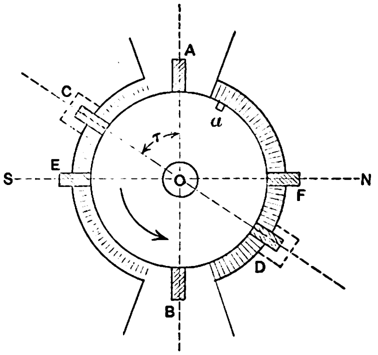


Fig.2

A. *Variable ratio by a change of the position angle between commutator brushes and resultant magnetic flux.* In the commutating machine shown diametrically in Fig. 1, let the potential difference, or alternating voltage between one point *a* of the armature winding and the neutral 0; that is, the star voltage, or half the diametrical voltage, be represented by the sine wave, Fig. 3. This potential difference is a maximum, *e*, when *a* stands at the magnetic neutral, at *A* or *B*.

If, therefore, the brushes are located at the magnetic neutral, *A* or *B*, the voltage between the brushes is the potential difference between *A* and *B*, or twice the maximum star voltage, 2*e*, as indicated in Fig. 3. If now the brushes are shifted by an angle τ, to position *C* and *D*, Fig. 2, the direct voltage between the brushes is the potential difference between *C* and *D*, or 2*e*

$\cos \tau$ with a sine wave. Thus, by shifting the brushes from the position *A*, *B*, at right angles with the magnetic flux, to the position *E*, *F*, in line with the magnetic flux, any direct voltage between $2e$ and *O* can be produced with the same wave of alternating voltage *a*.

As seen, this variation of direct voltage between its maximum value and zero, at constant impressed alternating voltage, is independent of the wave shape, and can, therefore, be produced whether the alternating voltage is a sine wave or any other wave.

Instead of shifting the brushes on the commutator, with fixed position of the commutator brushes the magnetic field poles may be shifted in the opposite direction, by the same angle, as shown in Fig. 4, *A*, *B*, *C*.

Instead of mechanically shifting the field poles, they can be shifted electrically, by having each field pole consist of a number of sections, and successively reversing the polarity of these sections, as shown in Fig. 5, *A*, *B*, *C*, *D*.

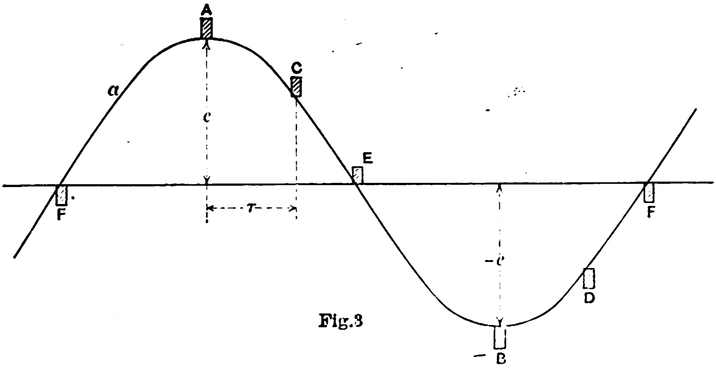


Fig.3

Instead of having a large number of field-pole sections, two sections are obviously sufficient, and the same gradual change can be brought about, by not merely reversing the sections, but by reducing the excitation to zero and bringing it up again in opposite direction as shown in Fig. 6, *A*, *B*, *C*, *D*, *E*. In this case, when reducing one section the other section must be increased by approximately the same amount to maintain the same alternating voltage.

In changing the direct voltage by mechanically shifting the brushes past the field poles, as soon as the brushes come under the field-pole faces self-inductive sparking on the commutator results, if the iron of the field poles were not kept away from the brush position by having a slot in the field poles, as indicated in the dotted line in Fig. 2, and Fig. 4*B*. With the arrangement in Figs. 2 and 4, this is not feasible mechanically, and these arrangements are therefore unsuitable. It is feasible, however, in the arrangements shown in Figs. 5 and 6; that is, when shifting the resultant magnetic flux electrically, to leave a commutating space between the polar projections of the field at the brushes, as shown in Fig. 6, and thus obtain as good commutation as in any other commutating machine.

Such a variable-ratio converter, then, comprises an armature with the brushes in fixed position, and field poles separated by interpolar spaces of such width as required for commutation. Each field pole consists of two parts, usually of different size, separated by a narrow space, and provided with independent windings. By varying the relative excitation of the two polar sections, an effective shift of the resultant field flux, and a corresponding change of the direct voltage, is produced.

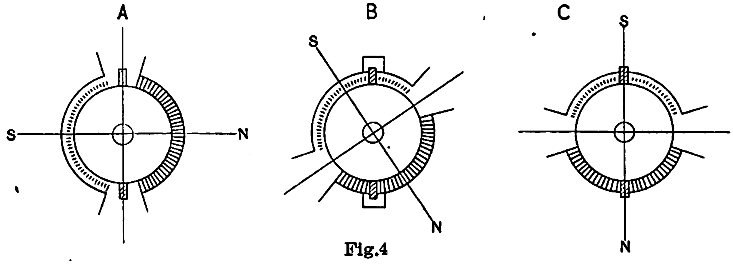


Fig.4

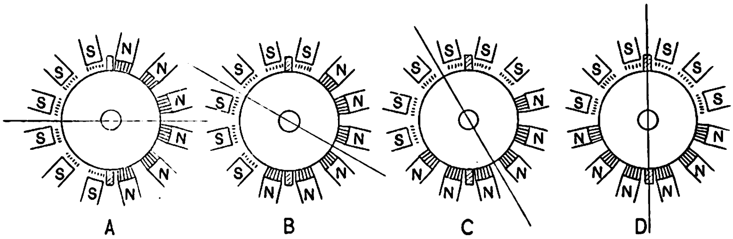


Fig.5

As this method of voltage variation does not depend upon the wave shape, by proper designing of the field pole faces and the pitch of the armature winding, the alternating voltage wave can be made as near a sine wave as desired. Experience shows, however, that the usual distributed winding of the commutating machine produces a sufficiently close approach to sine shape.

B. Variable ratio by change of wave shape of the star voltage. If in the converter shown diagrammatically in Fig. 7 the magnetic flux disposition, and the pitch of the armature winding is such that the potential difference between the point *a* of the armature and the neutral *O*, or the star voltage, is a sine wave, Fig. 8*A*, then the voltage ratio is normal. Assuming, however, that the voltage curve differs from sine shape by the superposition of some higher harmonics—the third harmonic in Fig. 8, *B* and *C*, or the fifth harmonic in Fig. 8, *D* and *E*. If, then, these higher harmonics are in phase with the fundamental, as in Fig. 8, *B* and *D*, they increase the maximum of the alternating voltage, and thereby the direct voltage; if these harmonics are in opposition with the fundamental, as in Fig. 8, *C* and *E*, they decrease the maximum alternating voltage and thereby the direct voltage, without appreciably affecting the effective value of the alternating voltage. For instance, a higher harmonic of 30 per cent of the fundamental, increases or decreases the direct voltage by 30 per cent, but varies the effective alternating voltage only by $\sqrt{1-0.3^2} = 1.044$, or 4.4 per cent.

The superposition of higher harmonics thus offers a means of increasing as well as decreasing the direct voltage, at constant alternating voltage, and without shift of the angle between brush position and resultant magnetic flux.

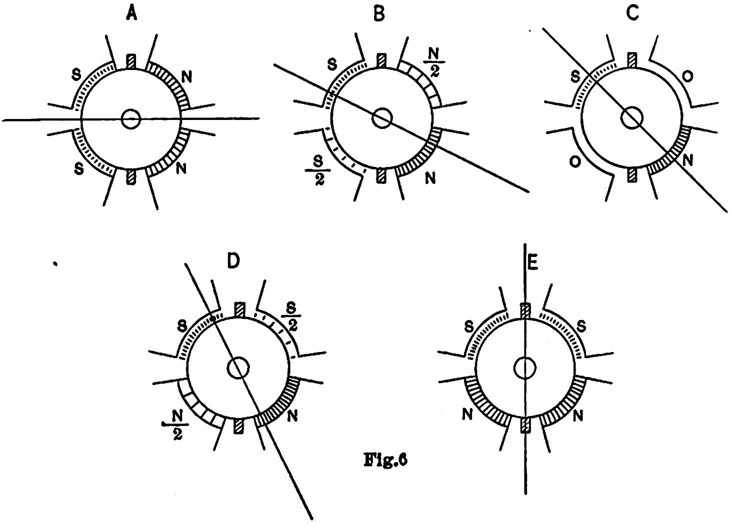


Fig.6

As, however, the terminal voltage of the converter does not only depend on the induced electromotive force of the converter, but also on that of the generator, and is a resultant of the two electromotive forces in approximately inverse proportion of the impedances from the converter terminals to the two respective induced electromotive forces, only such higher harmonics can be used for varying the converter ratio, which may exist in the star voltage, without appearing in the converter terminal voltage.

In general, in an *n* phase system an *n*th harmonic existing in the star voltage does not appear in the ring or delta voltage, as

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the ring voltage is the combination of two star voltages displaced in phase by $\frac{180}{n}$ degrees for the fundamental, and thus by 180 degrees, or in opposition, for the nth harmonic. Thus in a three-phase system, the third harmonic can be introduced into the star voltage of the converter, as in Fig. 8, *B* and *C*, without affecting, or appearing in the delta voltage, and can, therefore, be used for varying the direct voltage. The fifth harmonic can not be used in this way, but would reappear and cause a short-circuit current in the supply voltage, hence should be made sufficiently small to be harmless.

The third harmonic thus can be used for varying the direct voltage in the three-phase converter diagrammatically shown in Fig. 9*A*, and also in the six-phase converter with double-delta connection, as shown in Fig. 9*B*, or double star connection as shown in Fig. 9*C*, since this consists of two separate three-phase triangles of voltage supply, neither of them containing the third harmonic. In such a six-phase converter with double star connection, Fig. 9*C*, the two neutrals must not be connected together, as the third harmonic voltage exists between the neutrals. In the six-phase converter with diametrical connections, the third harmonic of the star voltage appears in the terminal voltage, as the diametrical voltage is twice the star voltage. In such a converter, if the primaries of the supply transformers are connected in delta as in Fig. 9*D*, the third harmonic is short-circuited in the primary voltage triangle, producing excessive currents which causes heating and interferes with the voltage regulation. This arrangement is, therefore, not permissible.

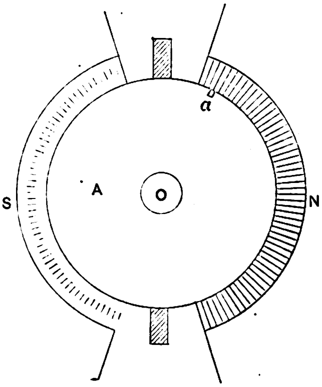

FIG. 7

If, however, the primaries are connected in star, as in Fig. 9*E*, and either three separate single-phase transformers, or a three-phase transformer with three independent magnetic circuits, is used, as in Fig. 10, the triple-frequency voltages in the primary are in phase with each other between the line and the neutral, and thus with isolated neutral cannot produce any current. With a three-phase transformer as shown in Fig. 11; that is, in which the magnetic circuit of the third harmonic is open, triple-frequency currents can flow in the secondary. This arrangement is therefore not satisfactory.

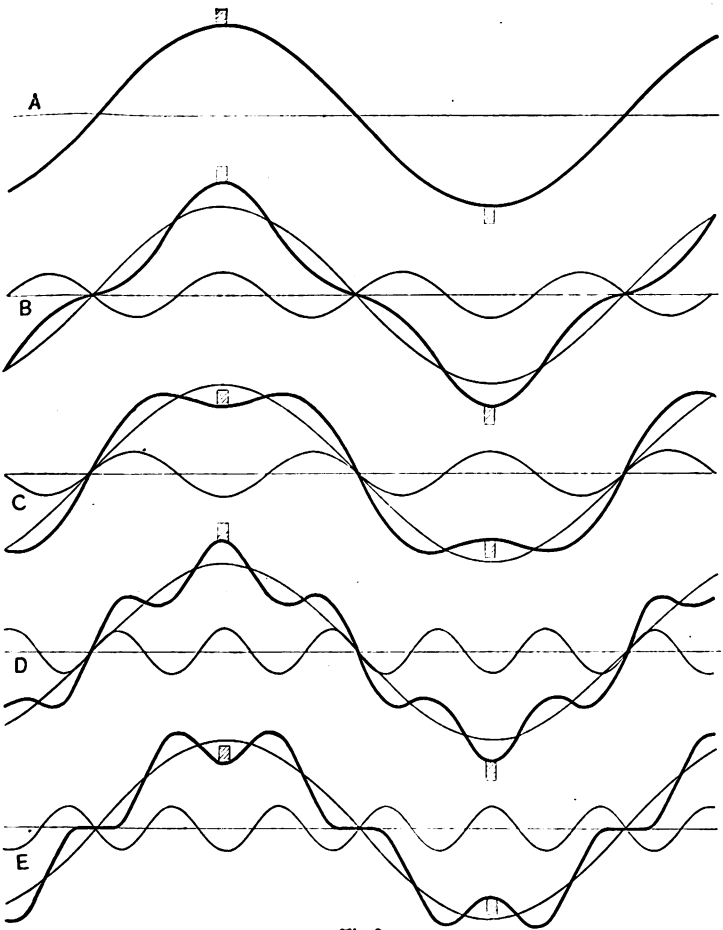

Fig.8

In two-phase converters higher harmonics can be used for regulation only if the transformers are connected in such a manner that the regulating harmonic which appears in the converter terminal voltage does not appear in the transformer terminals; that is, by a connection similar to that in Fig. 9*E* and 10.

As the direct voltage regulation of a three-phase or six-phase converter of this type is produced by the third harmonic, the problem is to design the magnetic circuit of the converter so as to produce the maximum third harmonic, the minimum fifth and seventh harmonic.

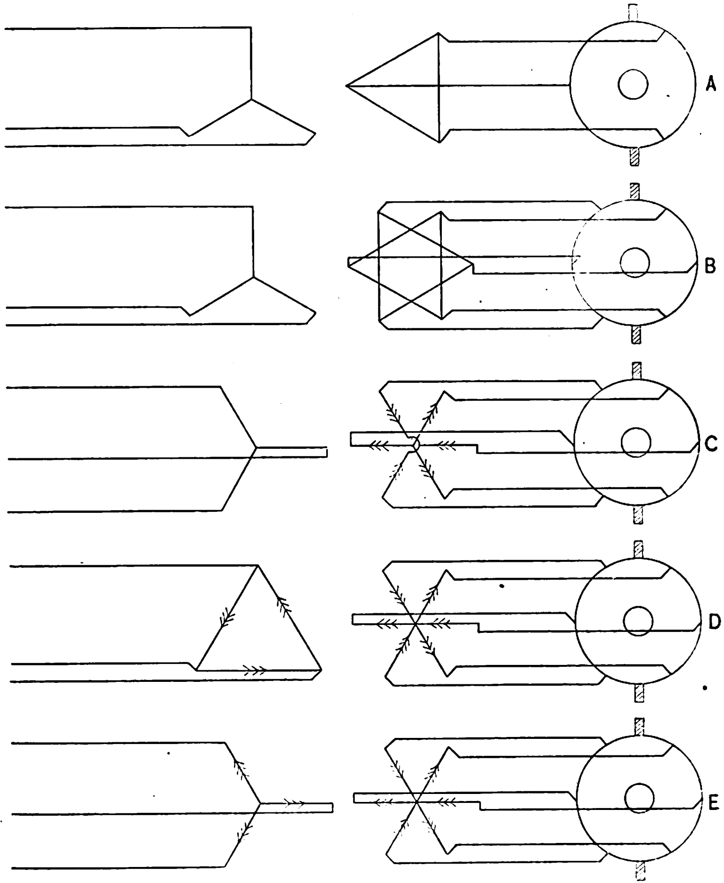

Fig. 9

There are thus two methods of producing a variation of direct voltage at constant alternating supply voltage. We can use either the one, or the other, or a combination of both. Here the question of commutation comes in. In the converter, at normal voltage ratio, the alternating current and the direct current also have a fixed ratio, derived from the voltage ratio by the law of conservation of energy. At this ratio, we find the resultant ampere-turns of the direct-current output equals the resultant ampere-turns of the alternating-current input, neglecting losses and phase displacement, and is opposite thereto. The converter, at normal voltage ratio, has no armature reaction, except the small armature reaction due to the energy current driving the armature round, and the magnetizing or demagnetizing reaction of the lagging or leading current.

Assume, however, by any one of the above described methods that the ratio is changed and the direct voltage is lowered below the value normally corresponding to the alternating voltage; the direct current is raised beyond that value corresponding to the alternating current, and there is a resultant armature reaction; that is, part of the direct-current armature reaction is not neutralized by the alternating current armature reaction, and so a small direct-current armature reaction remains.

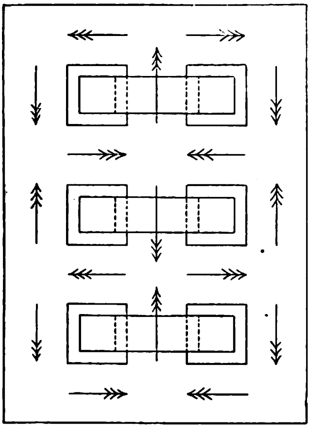

Fig.10

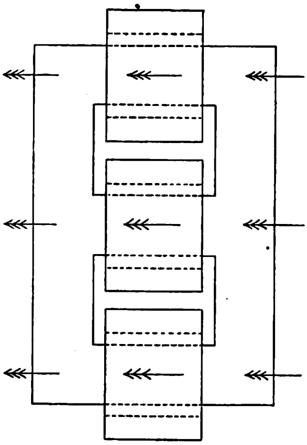

Fig.11

By raising the direct voltage, or lowering the alternating voltage the direct-current armature reaction is less than that of the alternating current, and thus a part of the alternating current-synchronous motor armature reaction remains uncompensated. A variable-ratio converter deviating from the normal voltage ratio—gives a small armature reaction, depending on the deviation from the normal voltage ratio, which at raised direct voltage is a synchronous motor reaction; that is, produces a commutating field and so takes care of the commutation; but at lower direct current voltage it is a direct current generator armature reaction; that is, tends to impair the commutation by opposing the current reversal. The armature reaction must therefore be taken care of.

In this case of raising the direct voltage, the synchronous motor armature reaction commutates, and if it is not sufficient for the desired commutation, we can shift the brushes to the edge of the next pole. If it should be too high, we can shift the brushes back to the preceding pole. But if we lower the voltage, we get a generator reaction, and therefore need a commutating field. In that case the outer side of the field poles is weakened and the center strengthened, and just where we need the commutating field in the three-part converter because we have to take care of a generator armature reaction—there the field corners weaken, and therefore this type of converter is liable to have poor commutation, when lowering the direct voltage, thus it is preferably not used for this purpose.

Consider now the type where we shift the magnetic field electrically. It can be shifted one way or the other. If shifted one way, it means that there is impressed on the brushes a part of the magnetic field of the main pole. If shifted the other way there is impressed a reverse field. In the latter case, there is interference with commutation, in the former, a commutating field is produced. The shift of the field for voltage regulation thus must be designed in the right direction. This commutating field may be too large. The type regulating by wave shape distortion, does not give the required commutating field; the type, regulating by shifting the flux, gives too high a commutating field. The problem, then, is to combine both types that is to use wave shape distortion, and in addition just as much shifting of the resultant flux as is necessary to produce the commutating field required for perfect commutation. Hence, this variable-ratio converter permits perfect control of the commutation by its design.

If there are three sections of the pole, the outside ones are weakened, the middle one strengthened, or inversely, for regulation by wave shape. Weakening only one outside one, and leaving the other outside one the same as the middle one, these gives a combination of regulation by shift of flux, and by change of wave shape, in any proportion, depending on the ratio of the pole arcs of the sections. In this case, however, two of the sections can be combined into one, and there results a converter with two unequal pole sections, as discussed in to-days papers. This is why in these converters there is used a two-part split-pole of arcs roughly in the proportion of one to two.

This disposes of the question of commutation. The next question is that of output. There is no doubt that if such a machine of 1000 kw. is designed to give any voltage from 200 to 300, it is larger than an ordinary 1000 kw. machine, of constant voltage, as it must be built to produce 300 volts, and to carry current giving the output at 200 volts. This is an inherent feature of all apparatus designed for a range of voltage, whether this range is produced as described above, or by phase control, or by a synchronous generator on the converter shaft, or in any other way.

From what I have said regarding armature reaction, the heating can be understood. At normal voltage ratio, the direct current and alternating current neutralize each other; when raising or lowering the voltage, this slightly modifies the resultant current, and also the heating. Without any further discussion hereof, it can however easily be seen that in any case the armature reaction and the excess of direct current over alternating current can never be the same as in the direct-current generator, and the heating thus must remain essentially less than in the direct current generator, and nearer to that of the standard converter.

Charles P. Steinmetz (by letter): *Armature reaction and commutation of variable ratio converter.* With the brushes in quadrature position to the resultant magnetic flux, and at normal voltage ratio, the direct-current generator armature reaction of the converter equals the synchronous-motor armature reaction of the alternating energy current; thus at unity power-factor the converter has no resultant armature reaction, while with a lagging or leading current it has the magnetizing or demagnetizing reaction of the wattless component of current.

A. In a variable ratio converter of type *A*, if by a shift of the resultant flux from quadrature position with the brushes, by angle τ, the direct voltage is reduced by factor $\cos \tau$, the direct current and therewith the direct-current armature reaction are increased, by factor $\frac{1}{\cos \tau}$, as by the law of conservation of energy the direct current output must equal the alternating current input (neglecting losses). The direct-current armature reaction F therefore ceases to be equal to the armature reaction of the alternating energy current, F_0, but is greater by factor $\frac{1}{\cos \tau}$

$$F = \frac{F_0}{\cos \tau}$$

The alternating-current armature reaction, F_0, at no phase displacement is in quadrature position with the magnetic flux. The direct-current armature reaction, F, however, appears in the position of the brushes, or shifted against the quadrature position by angle τ; that is, the direct-current armature reaction is not in opposition to the alternating-current armature reaction, but differs therefrom by angle τ, and can therefore be resolved into two components:

A component in opposition with the alternating current armature reaction, F_0; that is, in quadrature position with the resultant magnetic flux:

$$F'' = F \cos \tau = -F_0;$$

that is, equal and opposite to the alternating-current armature reaction and neutralizing it and:

A component in quadrature position with the alternating-current armature reaction, F_0, or in phase with the resultant magnetic flux; that is, magnetizing or demagnetizing:

$$F' = F \sin \tau = -F_0 \tan \tau$$

That is, in the variable-ratio converter, the alternating-current armature reaction at unity power-factor is neutralized by a component of the direct-current armature reaction, but a resultant armature reaction, F', remains, in the direction of the resultant magnetic field: that is, shifted by angle $(90-\tau)$ against the position of brushes. This armature reaction is magnetizing or demagnetizing, depending on the direction of the shift of the field τ.

It can be resolved into two components, one, at right angles with the brushes, and equal:

$$F_1' = F' \cos \tau = F_0 \sin \tau$$

and one, in line with the brushes, and equal:

$$F_2' = F' \sin \tau = F \sin^2 \tau = F_0 \sin \tau \tan \tau$$

as shown diagrammatically in Figs. 12 and 13.

There thus exists a resultant armature reaction in the direction of the brushes that is harmful for commutation, just as in the direct-current generator, except that this armature reaction in the direction of the brushes is only $F_2' = F \sin^2\tau$; that is, $\sin^2 \tau$ of the value of that of a direct-current generator.

The value of F_2' can also be derived directly, as the difference between the direct-current armature reaction F and the component of the alternating-current armature reaction, in the direction of the brushes: $F_0 \cos \tau$, that is:

$$F_2' = F - F_0 \cos \tau = F\ (1-\cos^2\tau) = F\ \sin^2\tau = F_0\ \sin\ \tau\ \tan\ \tau.$$

The shift of the resultant magnetic flux, by angle τ, gives a component of the magnetomotive force of field excitation $P_2 = P \sin \tau$, where P = magnetomotive of field excitation in the direction of the commutator brushes, and either in the direction of armature reaction, thus interfering with commutation, or in opposition to the armature reaction, thus improving commutation.

If the magnetic flux is shifted in the direction of armature rotation; that is, that section of the field pole weakened, towards which the armature moves, as in Fig. 12, the component P_2 of field excitation at the brushes in the same direction as the armature reaction, F', thus adds itself thereto and impairs the commutation. Such a converter is hardly operative. In this case the component of armature reaction in the direction of the field flux, F', is magnetizing.

If the magnetic flux is shifted in opposite direction to the armature reaction; that is, that section of the field pole weakened which the armature conductor leaves, as in Fig. 13, the component P_2 of field excitation at the brushes is in opposite direction to the armature reaction F', reversing it if sufficiently large, and gives a commutating or reversing flux R, that is, improves commutation so that this arrangement is used in such converters. In this case, however, the component of armature reaction in the direction of the field flux F' is demagnetizing, and with increasing load the field excitation has to be increased by F', to maintain constant flux. Such a converter requires compounding, as by a series field, to take care of the demagnetizing armature reaction.

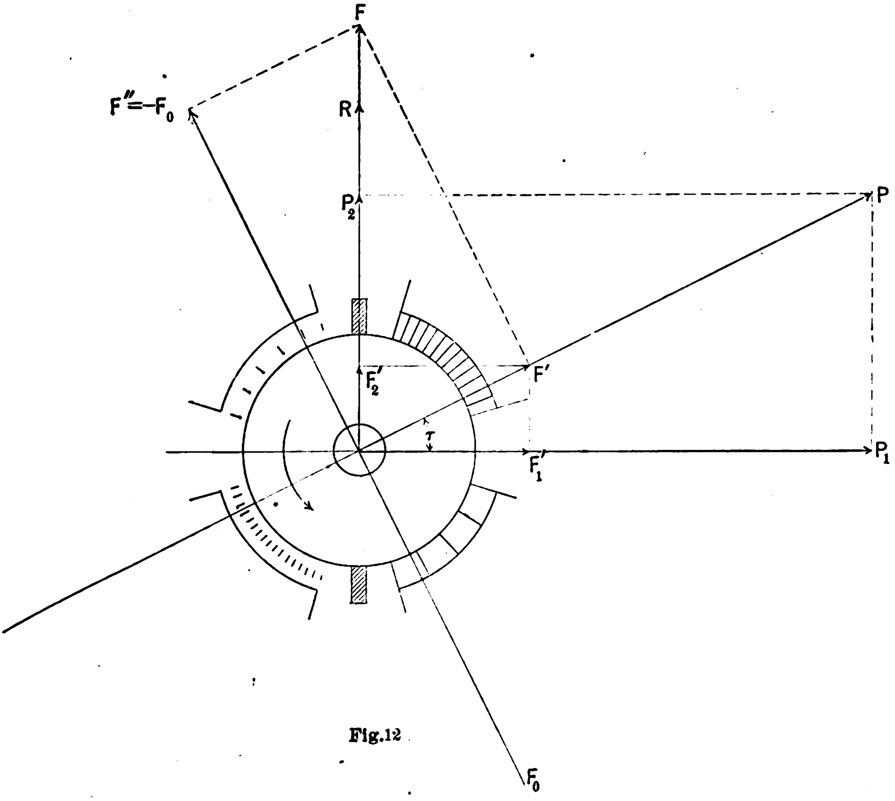

Fig. 12

If the alternating current is not in phase with the field, but lags or leads, the armature reaction of the lagging or leading component of current superimposes upon the resultant armature reaction, F', and increases it, with lagging current in Fig. 12, leading current in Fig. 13, or decreases it with lagging current in Fig. 13, leading current in Fig. 12. With lag of the alternating current, by phase angle τ, under the conditions of Fig. 13, the total resultant armature reaction vanishes, that is, the lagging component of synchronous motor armature reaction compensates for the component of the direct-current reaction, which is not compensated by the armature reaction of the alternating energy current. It is interesting to note, that in this case, as regards heating, output based thereon etc., the converter equals that of normal voltage ratio.

B. In a variable-ratio converter of type *B*; that is, operating

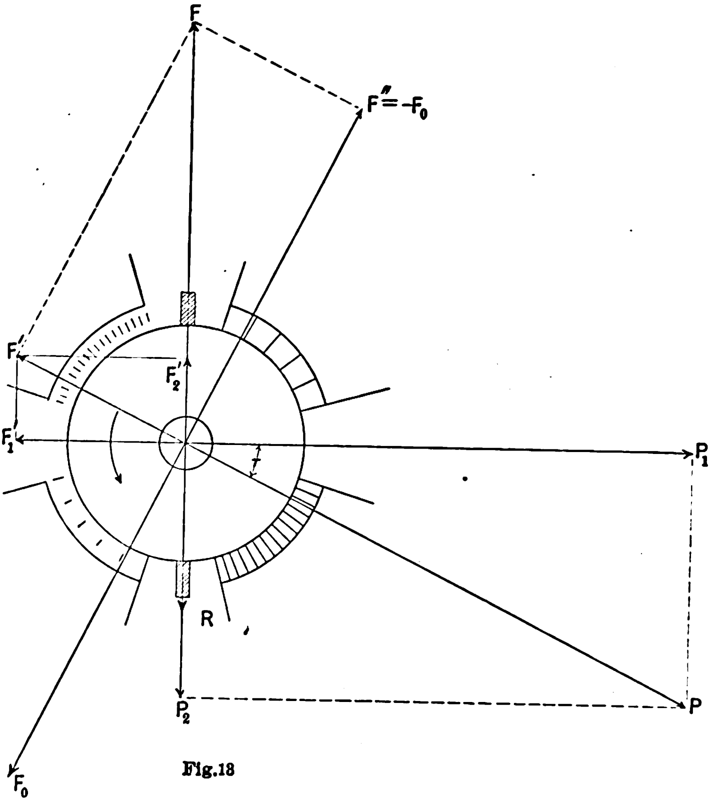

Fig.18

by wave shape distortion, let p equal ratio of direct voltage to that voltage which it would have with the same alternating impressed voltage at normal voltage ratio, where $p > 1$ represents an over normal voltage, $p < 1$ a subnormal direct voltage. The direct current, and thereby the direct-current armature reaction, then is changed from the value which it would have at normal voltage ratio by the factor $1/p$, as the product of direct volts and amperes must be the same as at normal voltage ratio, being equal to the alternating power input, minus losses.

With unity power-factor, the direct-current armature reaction F in a converter of normal voltage ratio is equal and opposite, and is neutralized by the alternating-current armature reaction F_0, and at a change of voltage ratio from normal, by factor p, and thus change of direct current by factor $1/p$, the direct-current armature reaction thus is:

$$F = \frac{F_0}{p}$$

hence leaves an uncompensated resultant.

As the alternating armature reaction at unity power-factor is in quadrature with the magnetic flux, and the direct-current armature reaction in line with the brushes, and with this type of converter the brushes stand at the magnetic neutral, that is, at right angles to the magnetic flux, the two armature reactions are in the same direction in opposition with each other, and so leave the resultant, in the direction of the commutator brushes:

$$\begin{aligned} F' &= F - F_0 \\ &= F\,(1 - p) \end{aligned}$$

The converter thus has an armature reaction, proportional to the deviation of the voltage ratio from normal.

If $p > 1$, or over normal direct voltage, the armature reaction is negative, or motor reaction, and the magnetic flux produced by it at the commutator brushes commutating flux. If $p < 1$, or subnormal direct voltage, the armature reaction is positive; that is, the same as in a direct-current generator, but less in intensity, and the magnetic flux of armature reaction tends to impair commutation. In a direct-current generator, by shifting the brushes to the edge of the field poles, the field flux is used as reversing flux to give commutation. In this converter, however, decrease of direct voltage is produced by lowering the outside sections of the field poles. The edge of the field may not have a sufficient flux density to give commutation with a considerable decrease of voltage below normal. therefore, a separate commutating pole is required, or this type of converter is used only for raising the voltage; for lowering the voltage the other type used, which operates by a shift of the resultant flux, and gives a component of the main field flux as commutating flux.

With a polar construction consisting of three sections this can be done by having the middle section at low excitation, the outside sections at high excitation for maximum voltage; and to decrease the voltage, raise the excitation of the center section, but instead of lowering both outside sections, leave the section in the direction of the armature reaction unchanged, while lowering the other outside section twice as much, and so produce in addition to the change of wave shape, a shift of the flux, nd thereby produce at the brushes a magnetic commutating field of any desired strength.

The distribution of current in the armature conductors of the variable-ratio converter, and the wave form of the actual or differential current flowing in the conductors, and the effect of the wattless current thereon, is determined in the same manner as in the standard converter, and from them is calculated the local heating in the individual armature turns, and the minimum armature heating.

The results in general are the same, showing a superiority of the six-phase over the two-phase, and of the two-phase over the three-phase arrangement. As regards the rating of the machine based on armature heating, the variable-ratio converter is intermediate between the standard converter and the direct-current generator, approaching the former, the less voltage ratio differs from the normal. The rating, of such a converter of a constant direct voltage differing from that corresponding to the alternating supply voltage, is far higher and the size therefore smaller than that of a direct-current generator. It approaches that of the standard converter the nearer the voltage ratio is to the normal.

Where, however, the converter is intended for operation over a considerable voltage range, as when connecting a storage-battery to an alternating-current system, the size of the converter is greater than that of a converter operating at constant voltage, in the same way and by the same amount as any apparatus intended for operation over a considerable voltage range; that is, the magnetic circuit of the machine must be ample to carry the magnetic flux of maximum voltage, while the conductor section and commutator size must be sufficient for maximum current. This increase of size is a necessary result of operation over a voltage range, irrespective of the method by which the change of voltage is brought about, whether by a change of the alternating impressed voltage, or by a change of the converter ratio. and so has nothing to do with the method of voltage regulation.

P. M. Lincoln (by letter): The description by Mr. Steinmetz of the actions taking place in a split-pole converter is beautifully simple and lucid. I fail to see, however, wherein Mr. Steinmetz has substantiated the claims made in opening his discussion; namely, that he would clear up the difficulties in regard to commutation, decrease in capacity, lower efficiency, variable wave form, etc., mentioned in my discussion.

As to the three-part-pole machine, the reduction in capacity necessary to obtain a reasonable voltage variation seems to put this type machine out of the running entirely. As to the two-part-pole machine, Mr. Steinmetz has failed to reconcile the conflicting requirements of wave form and commutation. Wave form demands that the commutating notch in the field be of zero width. Commutation, on the other hand, demands a notch in the field form of at least 20 per cent to 25 per cent of the space between brushes. This has been demonstrated by years of experience. Just how much will be required under the peculiar conditions of the two-part-pole construction is problematical, but it is impossible for me to conceive how it can be less than in a machine of normal design; and in view of the variable field strength at the commutating point, it seems that this notch should be considerably wider than in the normal design. In fact the necessarily wide variations of field strength at the commutating point raise serious questions as to the possibility of obtaining satisfactory commutation even with the most favorable notch widths.

I am deeply interested in Mr. Steinmetz' description of the variable-voltage converter, and I give mental assent to every one of his deductions, but I am disappointed that he does not explain away the above questions as well as the others raised by my discussion.

In closing his discussion, Mr. J. L. Woodbridge takes issue with my statement that rapidity of voltage change can be largely increased in the separate alternating current booster converter over anything possible in the split-pole machine, owing to the possibility of omitting dampers from the separate booster field, coupled with the impossibility of omitting them from the split-pole machine. He suggests that I did not take into consideration that in the case of a separate alternating current booster the strength of the main converter fields, (which must be damped) as well as the booster fields, must change before the voltage ratio of the combination can change. I wish to assure Mr. Woodbridge that I fully considered the matter in this light before making my statement. It is perfectly true that so long as its speed remains constant, neither the alternating nor the direct voltage of a converter can change without changing its field strength. Immediately upon a change in the voltage applied to the alternating current end of a converter, a current begins to circulate through its armature of such a nature as to cause the field value to change rapidly to that necessary to accommodate the changed alternating current value. The whole power of the system to which the converter is attached is available for bringing about this change in field flux. If the shunt field of the converter is excited from its own commutator, the shunt ampere-turns will assume a new value such as will, with proper design, virtually eliminate the armature current which causes the immediate adjustment of the field flux. It is the duty which falls upon the regulator that determines its speed of action, and in the case of the separate booster converter, the changing of the flux in the main converter fields is not a part of this duty. This condition was all gone over mentally before making the statement appearing in my discussion. I considered it so obvious as not to require statement.

Mr. Woodbridge further states that he has designed a damper to apply to the split-pole machine of such a nature that it does not interfere materially with the speed of voltage changes. To cause voltage changes in a converter of Mr. Woodbridge's design, a shifting of magnetic flux from one part of the pole face to another is required. To prevent hunting, a damper must be so designed as to prevent the shifting of magnetic flux from one part of the pole face to another. Mr. Woodbridge's requirement is, therefore, diametrically opposed to the essential object of a damper. I must, therefore, remain skeptical as to the efficacy of the new damper until further details are disclosed.

J. L. Burnham (by letter): Since the papers and discussions so far have been theoretical, it may be of interest to have some results from machines that have been built. The results given are based on observations of operation of one 200-kw. three-phase; one 500-kw. six-phase; and four 1000-kw. six-phase converters all having a range in voltage of 4 to 5; a 1000 kw. converter having a 6 to 7 voltage range; and a 2000-kw. six-phase converter having a range in voltage of 2 to 3. None of these machines had unusual armature winding pitch or tap connections to eliminate harmonics, as suggested in the papers by Messrs. Adams and Woodbridge, as all experimental data obtained showed that it was not necessary.

These machines were operated from a 13200-volt, 2000-kw. alternator over a one-half mile line through transformers connected delta primary, double-delta secondary; delta primary diametral secondary; star primary, diametrical secondary; star primary, double-delta secondary and two-phase primary, six-phase, double-T secondary. When running at no load, the alternating current minimum input for various excitations throughout the voltage range did not in any case exceed 8 per cent, except for the delta primary, diametral secondary connection of transformers. This 8 per cent alternating-current input includes all of the odd harmonics, except the third and its multiples, which are eliminated by transformer connections, in addition to no-load losses of the machine, which would amount to about 3 per cent. This result seems to confirm the calculated negligible value of harmonics given in the papers by Messrs. Adams and Woodbridge. At full load these harmonics are so small that they do not make an appreciable difference between kilovolt ampere and kilowatt readings.

The 200-kw. and 500-kw. machines mentioned above have passed the probation period of two years mentioned by Mr. Lincoln and Mr. Waters and have shown themselves to be the equal of machines with usual pole construction in general operating characteristics, such as commutation, stability, alternating current and direct-current starting, quiet running, etc. The efficiencies are, of course, dependent upon the voltage for each load. For voltages obtained by operating the two sections of the pole with excitation in the same direction, there is virtually no difference between sectional pole machines and the machine of standard pole construction. When the auxiliary section is excited to reverse polarity of the main section, the core-loss and loss in armature conductors, due to load current, will be greater than for a machine of standard construction amounting at extreme lower voltage to between one and two per cent. It will, therefore, be seen in the table given later that the split-pole machine will be more efficient at the higher voltages of its range than the converter with a pole piece of usual construction and its induction or booster regulator, and approximately the same efficiency at the lower voltages of the range.

In regard to three-wire operation, it may be stated that this has been successfully accomplished with transformers connected star primary, diametral secondary, deriving the neutral from the transformers. Throughout the 3 to 4 range of voltage, with an unbalancing between the two sides of 70 per cent of the full load current of the machine, the machine was perfectly stable, commutating sparklessly and running quietly. The harmonic currents were negligible and direct current voltage steady. This is a guaranteed condition of operation.

Mr. Water's statement that a slight displacement of poles of the split-pole machine from their proper position would cause excessive equalizing current to flow in a multiple-wound armature has no weight, since the same result would be obtained from displacement of poles of usual construction or with interpole construction.

No mention has been made of the performance of a split-pole converter as a compound-wound machine. From tests made on a machine having a two-section pole with shunt winding on the main pole and a series winding on the auxiliary pole, an overcompounding of approximately 15 per cent. was obtained without taking a wattless component of current in excess of that given at approximately 98 per cent. power-factor full load the alternating voltage at collector rings being held constant. With the usual arrangement of compound-wound converters with 15 per cent reactance coils in the collector lines, a variation in wattless component of over 100 per cent would be required to give the same overcompounding. Assuming that the shunt field is excited to give 50 per cent of the full-load current lagging at no load, the leading wattless component at full load would be somewhat in excess of 50 per cent full-load current, which would give a power-factor in the converter of less than 90 per cent. In addition to the advantage of running at practically unity power factor with a compound-wound split-pole converter, the commutation will be fully as good when the machine is operating with rotation such that the auxiliary pole will be on the leading side of the main pole as with the reverse, or usual rotation. With proper proportions of auxiliary field, the commutation may be improved by depending upon the auxiliary pole for commutating flux, which will be proportional to the load, the same as in a commutating pole machine. The auxiliary section will then serve as a commutating, as well as a compounding pole.

The following table of approximate costs, floor space, and efficiencies, are based on 1000-kw. units with a voltage range 4 to 5, all to meet the same guarantees. The machine of usual pole construction with induction regulator is taken as the basis for comparison.

Converter with Usual Pole Construction

	With induction regulator per cent.	With revolving armature a.c-booster per cent.	With revolving field a.c-booster per cent.	Split pole converter per cent.
Cost	100	112	106	100
Efficiency mid-voltage full-load	94.5	94.25	94.5	95
Weight	100	106	106	97
Floor space	100	103	107	96

J. L. Woodbridge: Professor Adams has presented a very interesting discussion of the theory of the split-pole converter, differing in many respects from mine. A comparison of the two methods of analysis will show that while starting from the same point, namely, the harmonic analysis of the curve of field distribution, they both arrive at practically the same conclusions by two different routes and they therefore fit in very well together. In each analysis certain points are covered which do not appear in the other.

There are one or two points brought up by Mr. Lincoln to which I would like to refer. He has called attention to the limited width of the neutral space for commutation shown in Fig. 17 of my paper. It must be understood that Fig. 17 shows the field distribution at the armature periphery including the field fringe, and the distance between the pole tips would therefore be greater than the 30° space shown in this Fig. In fact this Fig. was taken from a machine actually designed, built, and operated. This question of commutation has however been so thoroughly covered by Dr. Steinmetz and by Mr. Burnham, from both theoretical and practical standpoints, that further comment appears unnecessary.

In comparing the split-pole converter with a series alternating-current booster, Mr. Lincoln has taken the stand that the latter would act more quickly, owing to the fact that there is a smaller amount of field flux to change. Mr. Lincoln does not seem to have taken into account the fact that with a converter having an alternating-current booster mounted on the same shaft, if it is desired to vary the direct voltage without altering the alternating voltage or the power-factor, it will be necessary to vary the fields of both machines. It is impossible to vary the direct voltage of the converter without changing its field strength. While this may be brought about without changing the excitation of the field windings, by simply changing the voltage applied to the collector rings and permitting the wattless current thus produced in the armature to magnetize or demagnetize the field, nevertheless this change of field strength must be brought about. The voltage at the brushes cannot be reduced without actually reducing the flux through which the armature winding is passing. Some reduction in excitation will result from the reduced voltage applied to the shunt-field winding of a self-excited converter, but unless a prohibitive amount of iron is used in the magnetic circuit so as to work below the knee of the saturation curve this change in excitation will produce but little effect on the field strength, and the remainder must be produced by wattless currents in the armature. Such a combination cannot, therefore, operate at unity power-factor without providing for simultaneous control of both fields.

In regard to damping devices, I would say that a special design of damper has been worked out for the three-part pole which will not interfere with the quickness of action. It permits the field flux to vary symmetrically with respect to the axis of the field while retarding any tendency to shift the entire field one way or the other. For the two-part field the main section can be provided with an ordinary copper-ring damper, since the field strength in this section is not varied. Where the auxiliary field section is controlled automatically, no damping device will be required, as the automatic controller will counteract any tendency to a variation of flux in this section other than that which is required for operation.

Many of Mr. Lincoln's objections to the split-pole converter appear to be based on the assumption that it is impossible to eliminate the higher harmonics from the wave-form. In this connection it may be well to emphasize what has already been brought out in this discussion; namely, that the variation of voltage ratio in the split-pole converter is not *dependent* upon these higher harmonics, but that these are merely incidental and their elimination by a proper design of the machine does not limit the change of ratio obtainable. In the three-part pole the third harmonic determines the voltage ratio, but this does not appear in the wave form with three-phase connection. In the two-part pole it is the shifting of the entire field that produces the change of voltage ratio, and this result may be obtained with a pure sine wave of fundamental frequency as has been so clearly shown by Dr. Steinmetz. Mr. Burnham has also shown that in the machines of this type actually built, these harmonics are quite negligible, even without the introduction of special features in the design adapted to minimize them.

G. E. Brown (by letter): Referring to Fig. 25, a test made on a 1000-kw. converter of the two-part-pole type recently put into commercial service, gave data very similar to that indicated in these curves. The converter was operated at no load with constant alternating voltage, and the direct voltage varied from 185 to 310. The normal direct voltage is 270, which requires no current in the auxiliary field circuit.

Referring to the statement that the minimum disturbance of power-factor occurs when working on either side of *Fo* as shown in Fig. 15, it is also evident from Fig. 25 that less change in the main field current is necessary to hold unity power-factor when the converter is operating below normal voltage than when it is operating above normal voltage. In this test, with the converter operating at no load from 185 to 270 volts, it was found that a variation in the main field current of about one per cent was necessary in order to maintain unity power-factor.

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CHARACTERISTICS OF MOTORS FOR LARGE SHEARS

BY BRENT WILEY

The function of a fly-wheel in a system with a rapidly fluctuating load is to equalize the power requirements, thus reducing the sudden shocks to the moving parts and thereby the strains on the machine frame and both the mechanical and electrical strains on the driving motor. For the fly-wheel to be effective the speed characteristic of the motor should be such that the motor will slow down as the load increases and will increase in speed as the load decreases. In the case of large shears the full working load is applied suddenly and the fly wheel is called upon to deliver energy through a very short space of time, varying from one-half a second to two seconds, according to the size of the machine and the size and condition of the material cut. Thus it is evident that the speed characteristics of the driving motor must be inherent, as the time is too short to depend upon a practical control means for changing the motor characteristics.

The ideal working condition for motor-driven shears would be one in which the fly-wheel does all of the cutting work, leaving for the motor only the friction load and the work of accelerating the fly-wheel after the cutting and subsequent slowing down period. The results of a test made on a large bloom shears, which is referred to later, show that this ideal condition can be approximated very closely when the speed characteristics of the motor are properly chosen.

Before outlining the exact conditions which the motor speed characteristics should meet, it would be well to analyze the speed curves of a shunt, a standard compound, a 50 per cent compound, and a series direct current motor. These curves as shown in Fig. 1 are designated by the letters *A*, *B*, *C* and *D*, respectively, and are given for a 50 h.p., 220-volt, direct-current motor.

For shears requiring a motor of 25 h.p., or of larger capacity, the friction load will approximate 25 per cent of the motor rating; for smaller shears the friction load varies from 15 per cent to 20 per cent of the full load.

The speed variation for a given change in load and the percentage of energy given up by the fly-wheel for the respective changes in speed are as follows:

Curve A.

Shunt motor, speed variation from light to full load . 5 per cent.
The energy of a fly-wheel varies as the square of the speed and the amount given up for 5 per cent speed variation is .... 10 per cent.

Curve B.

Standard compound motor, speed variation from light load to full load .... 15 per cent.
Standard compound motor, speed variation from friction or 25 per cent load to full load .... 10 per cent.
Energy given up by fly-wheel for 10 per cent speed variation .... 19 per cent.

Curve C.

50 per cent compound motor, speed variation from light to full load .... 50 per cent.
50 per cent compound motor, speed variation from friction or 25 per cent load to full load .... 30 per cent.
Energy given up by fly-wheel for 30 per cent speed variation .... 51 per cent.

Curve D.

Series motor, speed variation from 25 per cent load to full load .... 66 per cent.
Speed at 25 per cent load .... 1500 rev. per min.
Speed at full load .... 525 rev. per min.

With but few exceptions the electric motor drive is now used in all machine shops, and the replacing of worn-out engines with motors for individual and group drive is completing this evolution. Where such a change is to be considered in regard to engine-driven shears, it is comparatively a simple matter for an engineer to determine the size of the motor and the proper speed characteristics to give the best results. For example, in the case of a large hot bloom shear

The fly-wheel capacity of the machine .... *A* h.p. seconds.
Friction load of machine .... *B* amperes.
(obtained by test) .... (at a given voltage)
Cutting period .... 2 seconds.
Period between cuts .... 6 seconds.
(This cycle is to be considered continuous.)

If the power is cut off when the machine is running light at full speed, the number of consecutive cuts that can be made before the machine comes to rest is four. For the ideal case, where the fly-wheel does all of the work, it should give up 25 per cent of its energy per cut and must slow down 13 per cent.

Let the light load of the motor = *C* rev. per min.

During the cutting period the speed must fall to *C* rev. per min. 100 per cent − 13 per cent = 87 per cent *C* rev. per min.

Energy delivered by the fly-wheel during two seconds' cutting period and energy stored in the fly-wheel during the six seconds interval = 25 per cent *A* h.p. seconds.

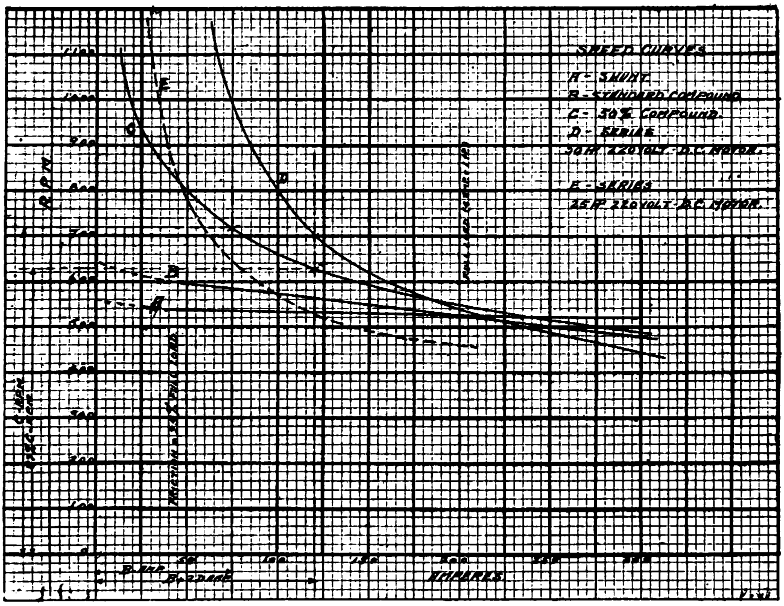

FIG. 1

Let the average current required to store 25 per cent *A* h.p. seconds energy in the 6 seconds interval = *D* amperes.

The current curve which corresponds to the power curve with constant voltage will vary through an economical range when the motor speed-characteristic governs the variation as follows:

The minimum value of the current should be equal to a friction load at the end of the interval between the cuts. The maximum value of the current should be equal to the friction load plus twice the value of the average current required to store the fly-wheel energy expended during one cut. The curve in Fig. 2 illustrates this.

During the cutting period the current rises to a maximum value as shown at point *X*, and falls to a frictional load value as shown at *Y* at the end of the 6-sec. interval. Thus, at the point *Y*, *B* amperes corresponds to *C* rev. per min., and establishes one point on the motor speed curve. This shows that it requires *D* amperes as an average to store the 25 per cent *A* h.p. seconds energy in the fly-wheel. Thus the maximum value of the current at point *X* equals 2 *D* amperes, which must correspond to 87 per cent *C* rev. per min., and a second point on the motor curve is established. By this means a speed curve for the working range required can be plotted. As an illustration, these points are designated on curve *C*, Fig. 1.

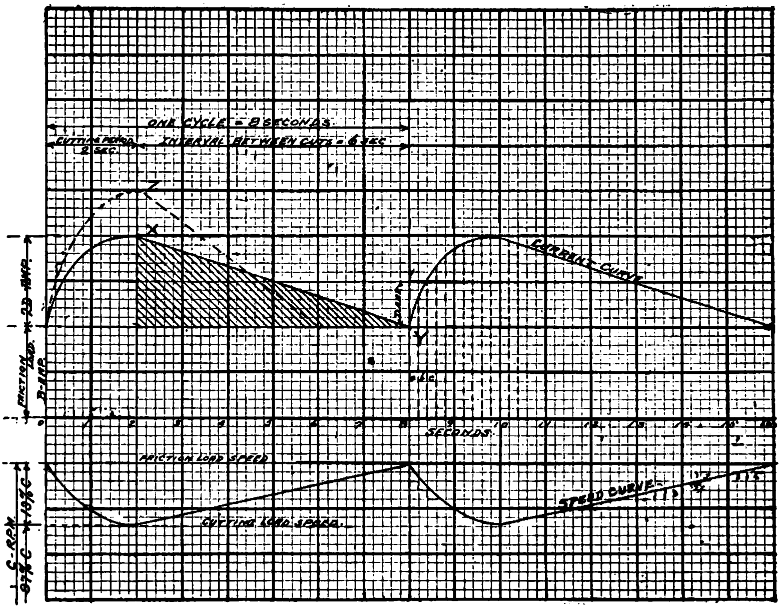

FIG. 2

The heating effect of the motor load varies as the square of the current and is represented by the square root of the mean square current. This value of current can be closely approximated by dividing the current curve into a number of parts along the time ordinate, squaring each sectional current value and multiplying by the time-increment. These several values are then added and the sum divided by the total time period. The square root of this dividend is the square root of the mean square current. For example, refer to Fig. 2.

Square root mean square current

$$= \sqrt{\frac{(a^2 \times 0.2) + (b^2 \times 0.2) + (c^2 \times 0.2) \text{ etc.}}{8}}$$

and this is the value of a continuous current which would produce the same heating effect as the varying load shown. The capacity of the motor required for the above condition can thus be calculated.

With the principal portion of the speed curve constructed and the capacity of the motor known, the next point for consideration is the type of motor winding and consequently the speed characteristic which is best suited for the given conditions.

As has been explained before, the speed variation of a series motor covers too great a range between the friction load, or 25 per cent full load, and the working of full load of the motor. This value is approximately 66 per cent, and therefore the series motor can be eliminated from the list.

The next motor to be considered is one with a 50 per cent compound winding, in which case the full-load speed is 50 per cent of the light-load speed.

Fig. 3 is a recorded current curve of a 50 per cent compound motor operating a large bloom shears which has the following characteristics:

Style of machine	Vertical, bloom.
Maximum section the machine will cut	10 in. by 10 in.
Weight of fly-wheel	20,000 lb.
Diameter of fly-wheel	9 ft. 10.5 in.
Section of fly-wheel rim	12 in. by 13 in.
Rev. per min. of fly-wheel	110
Energy of fly-wheel at friction load	2500 h.p. for 1 sec.
Size of motor	50 h.p., intermittent rating.
Voltage of motor	220
Type of motor winding	50 per cent compound.
Motor	direct-current, geared
Motor speed	500 rev. per min. full load.
Friction load	50 amperes, 235 volts, 800 rev. per min.
Cutting load, maximum	110 amperes, 235 volts.

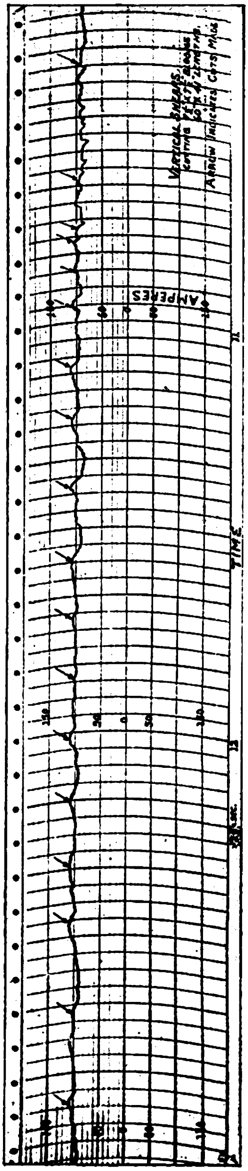
VERTICAL SHEARS.
ARROW INDICATES CUTS MADE
AMPERES
TIME
150
50
0
50
150

FIG. 3

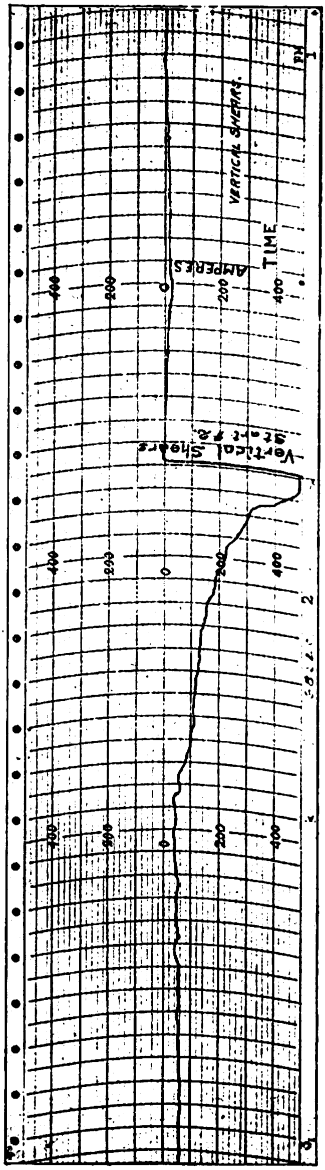
VERTICAL SHEARS.
AMPERES
TIME
Vertical Shears
400
200
0
200
400

FIG. 4

Section of material cut......................7.5 in. by 7.5 in.
Kind of material cut..............................hot steel

When the machine is running light at full speed and the power is cut off the number of consecutive cuts that can be made before machine comes to rest is four.

Motors used for intermittent duty, such as street car and crane service, are given an intermittent rating and will operate at full load for one hour without injurious heating; this heating is generally stated as 75 degrees cent. rise above the surrounding atmosphere. The above motor is rated on this basis, and the continuous load which it will carry with the same temperature rise is equal to practically one-half of the 1-hr. rating.

As shown on the curve, the motor is working between an average minimum load of 95 amperes and a maximum of 110 amperes. Estimating on the square root of the mean square basis, the equivalent heating current is approximately 100 amperes at 225 volts; this requires a 25-h.p. motor, continuous rating, or a 50-h.p. motor of intermittent rating.

The starting conditions as shown in Fig. 4 require a maximum of 100 h.p. which falls gradually to the friction load of 125 h.p. in 40 sec.

The curve in Fig. 3 shows virtually a uniform load on the motor, a much greater load than that given for the theoretical case in Fig. 1. An analysis of the condition shows, however, that the motor is working in a very steep portion of its speed curve; and the speed change for this working portion of the 50 h.p., 50 per cent compound-wound motor of intermittent rating is equal to 75 per cent of the speed change of a 25 h.p. series motor of continuous rating.

50 per cent compound motor 95 ampere 670 rev. per min.
" " " " 110 " 640 rev. per min.
Reduction in speed................. 30 rev. per min. = 4.5 per cent.
Series motor.............. 95 ampere 580
" " ....110 ampere 545
Reduction in speed................. 35 rev. per min. = 6.0 per cent.

The steeper the speed curve the more gradual is the fall of the current curve from the peak to the minimum value. Referring to the theoretical curve in Fig. 2, a motor with a certain percentage of compounding will require a maximum current, as designated at point *X*, to give the required speed change of 13 per cent; a motor with less compounding will require a maximum current rising to point *Z* for the same speed reduction. The shaded portion of the curve from point *X* to point *Y* represents the work done in restoring energy to the fly-wheel. It is obvious that an increase in the peak load or vertical component causes a corresponding decrease in the horizontal or time ordinate, as the area described by the curve beyond the peak remains constant. Therefore the steeper the motor speed-curve the more gradual the decrease of current value between the cutting periods. On account of this sluggish characteristic, it requires quite an appreciable time, virtually 14 seconds, Fig. 4, for the motor described above to increase the speed of the fly-wheel from the speed corresponding to 110 amperes to that corresponding to 50 amperes, or friction load. As a cut is made in about every 9 sec. the minimum value of the current does not reach the friction load. This is the principal reason why the obtained load curve is so much smoother than the theoretical curve of Fig. 2.

For the particular application given above, the 50 per cent compound motor proves to be a fairly good series motor regarding speed characteristics; it requires only a slight increase in load to give the speed reduction required by the fly-wheel in order that it may do the greater portion of the work. Compared with its continuous electrical capacity, this type of motor has great mechanical strength, and it is capable of standing heavy overloads for a short period of time. Thus it is apparent that both mechanically and electrically this motor has better characteristics than the motor of continuous rating for a heavier kind of work.

The curve of Fig. 5 shows the working load of a hot bloom shears driven by a direct-current, 220-volt motor of 25 per cent compounding. The general characteristics of the machine and motor are as follows:

Style of machine	horizontal bloom.
Maximum section the machine will cut	10 in. by 10 in.
Length of blade travel	15 in.
Rev. per min. of cam or crank-shaft operating blade	17 at 850 rev. per min. of motor.
Weight of fly-wheel	12,700 lb.
Diameter of fly-wheel	8 ft.
Section of fly-wheel rim	10 in. by 12 in.
Rev. per min. of fly-wheel at friction load	350
Energy of fly-wheel at 350 rev. per min	5900 h.p. for 1 sec.
Size of motor	125 h.p.
Type of winding	25 per cent compound.
Motor	direct-current, geared.

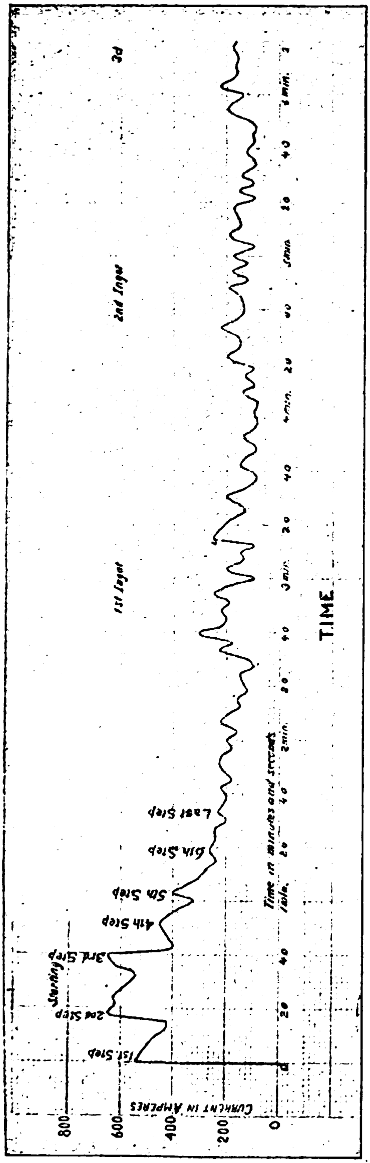
CURRENT IN AMPERES
800
600
400
200
0
1st Step
2nd Step
Starting
3rd Step
4th Step
5th Step
6th Step
Last Step
1st Ingot
2nd Ingot
3d
Time in minutes and seconds
1 min.
20
40
2 min.
20
40
3 min.
20
40
4 min.
20
40
5 min.
20
40
6 min.
TIME

FIG. 5

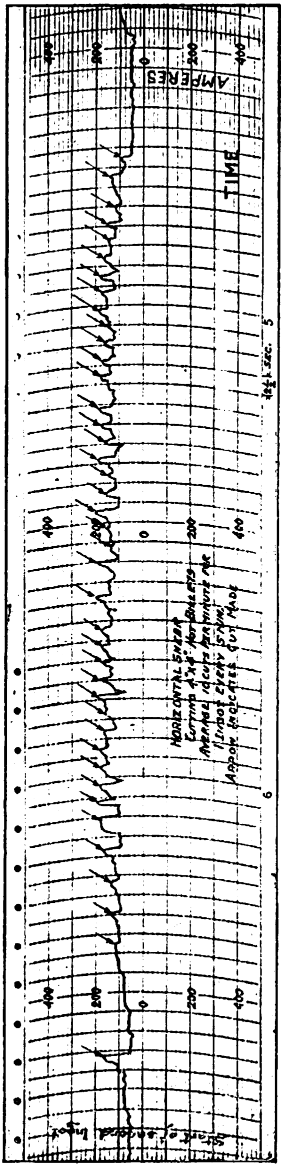
400
200
0
200
400
AMPERES
TIME
5
12½ sec.
6
HORIZONTAL SHEAR
CUTTING 4"x4" HOT BILLETS
AVERAGE 10 CUTS PER MINUTE PER
1 INGOT EVERY 5 MIN.
ARROW INDICATES CUT MADE
Start of second ingot

FIG. 7

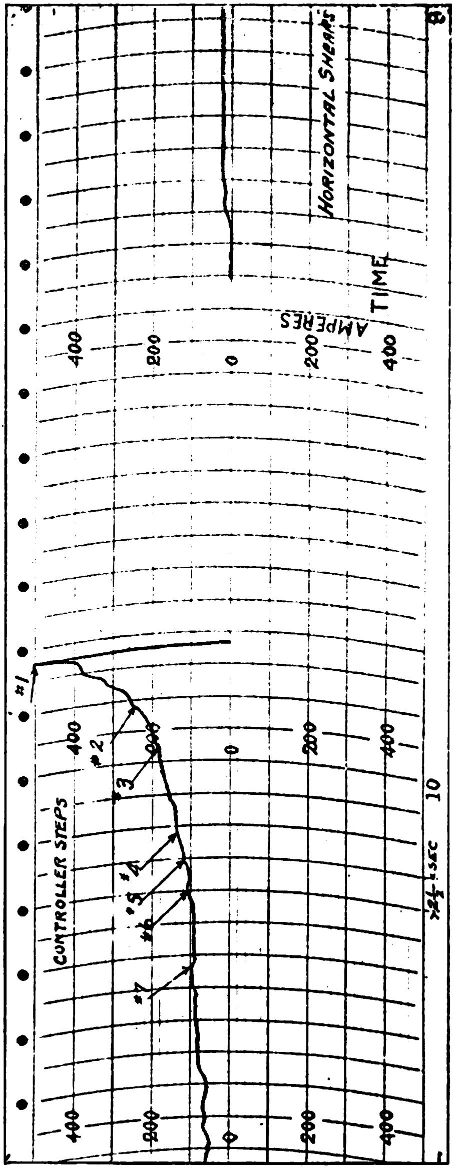
HORIZONTAL SHEARS
TIME
AMPERES
400
200
0
200
400
CONTROLLER STEPS
#1
#2
#3
#4
#5
#6
#7
10
2½ SEC

FIG 6

Motor speed	660 rev. per min. full load.
Friction load	100 amperes at 225 volts, 850 rev. per min.
Cutting load	200 amperes, at 225 volts.
Section of material cut	8.5 in. by 7.25 in.
Kind of material cut	hot steel.

When the machine is running at full speed and the power is shut off, the number of consecutive cuts that can be made before machine comes to rest is four.

The curve was plotted from readings taken at 3-sec. intervals The current reaches a maximum value of 300 amperes and is much more fluctuating than that indicated by the curve of Fig. 3, although the fly-wheel effect is more than double. With a motor of increased compounding the load fluctuation could be materially decreased.

The current would have excessive peak values with either a standard compound or shunt motor, although it has been found in some cases that for the same work done the heating effect on the standard compound motor was 25 per cent less than that on a shunt motor.

Increasing the fly-wheel capacity of the system has the same effect on the load curve as increasing the compounding of the motor, and it will consequently tend to flatten the load curve. If the fly-wheel capacity is decreased the load becomes very fluctuating, which is the same as decreasing the compounding of the motor, giving it a flatter speed curve. Fig. 6 shows the starting current and Fig. 7 the running current of a hot bloom shear driven by a motor of standard, or 15 per cent, compounding. If the fly-wheel capacity of this machine or the compounding of the motor were increased, a flatter current curve would be obtained.

Horizontal billet.

Maximum section the machine will cut	5 in. by 5 in.
Rev. per min. of cam or crank operating blade	28
Weight of fly-wheel	3000 lb.
Diameter of fly-wheel	5 ft. 6 in.
Section of fly-wheel rim	14 in. by 3 in.
Rev. per min. of fly-wheel	190
Size of fly-wheel	60 h.p.
Voltage of motor	220
Type of winding	standard compound.
Motor	direct current, belted.
Speed of motor	640 full load.
Cutting load	45 amperes at 230 volts.

Section of material cut........................4 in. by 4 in.
Kind of material cut..............................hot steel.

When the machine is running light at full speed and the power is cut off, the number of consecutive cuts that can be made before machine comes to rest is three.

ALTERNATING-CURRENT MOTORS FOR SHEARS

The motors considered are designed for either 25-cycle or 60-cycle, three-phase circuits and are of the induction type. When it is necessary to start a fly-wheel type machine frequently, the motor should have a wound rotor provided with slip rings and external resistance for control. This type of motor gives very good starting conditions, as full-load torque is obtained at approximately 1.25 times full-load current as compared with 3 to 3.5 times full-load current for full-load torque with a squirrel-cage rotor.

Shears are usually operated continuously, so the starting current required is not of particular importance. It is desirable to have a motor of simple construction for continuous duty, and although some sacrifice is necessary regarding starting conditions, an induction motor with a cage secondary should generally be used for operating shears. The motor should be provided with high-resistance end-rings, as this form of construction gives very good starting conditions. It is possible to double the starting torque for an equal amount of current with a decrease of efficiency of not more than 4 per cent at full load. A second advantage in using high-resistance rings is that the motor has a speed characteristic very similar to that of a direct-current compound-wound motor, thus allowing the fly-wheel to be effective during the cutting period.

The amount of resistance that can be included in the end-rings without undue heating is limited, as this heat energy must be dissipated in the motor. Where the motor operates continuously under virtually full load the maximum slip that can be obtained with high-resistance rings is approximately 10 per cent; but for intermittent service the slip can be increased to 15 per cent without undue heating. The efficiency and power curves of the motor will be similar to those of a standard direct-current shunt-wound motor having sufficient resistance in its armature circuit to give 15 per cent drop in speed from light to full load; in other words, the slip of the motor varies according to the resistance in the end-rings. As the fly-wheel effect obtained from the system varies as the square of the speed at the high and low points during the cutting period, a slight increase in the resistance will produce a material reduction of the maximum load on the motor.

In shearing plates, the load is applied gradually and a motor with 15 per cent slip will have a fairly smooth load curve, the fly-wheel being of liberal proportions. In the cases of hot bloom and scrap shears, where the section to be cut is quite large and practically square, the nature of the work becomes more severe. The actual cutting period is short and the power required large, which makes it necessary to include large fly-wheel capacity; and in order to prevent excessive loads motor should have a steep speed-curve. In the case of direct-current work it has been shown that increasing the compounding of the motor to 50 per cent has materially improved conditions, giving in the case shown almost a uniform load curve. For induction motors, however, 15 per cent slip is a practical limit, therefore to reduce the peak load for the heavier classes of machines fly-wheel capacity must be added.

In any class of machines where the load is intermittent, especially when cast tooth gears are used in the reduction, the driving motor will be subject to considerable vibration. In many cases it is necessary to mount the motor on a frame or bracket support, although it is difficult to provide sufficient rigidity with this construction. This vibration causes undue wearing of the motor-bearings and tends to deteriorate the rotor-windings. The most effective way to prevent this vibration where gearing is to be used is to mount flexible coupling between the rotor and the driving pinion, which is keyed to a short length of shaft supported by two bearings. This form of construction has been adopted for a number of different drives where the work is very severe. It gives excellent results with little wear of the coupling parts and shows a decided decrease in motor maintenance.

The starting conditions are rather severe when the machine has large fly-wheel capacity and for shears as described above. The motor-starting apparatus should be of liberal capacity and should be provided with protective means to insure a gradual starting of the motor, thus preventing excessive starting currents. An autostarter is used for this work.

The starter consists of a double-throw, oil-immersed switch with the autotransformers mounted in the same case. Several extra taps are provided so that the most suitable starting condition can be obtained. In starting, the handle of the autostarter is first thrown to the right which closes the switch on the starting side. A lock is provided to prevent the handle from being thrown in the wrong direction, and unless held in position by hand on the starting side it will return automatically to the off position. After the motor has attained a nearly constant speed the handle is thrown quickly to the left and is locked automatically.

Fuses or a circuit-breaker may be employed to protect the motor against overloads while running, and these can be so connected that the starting current may exceed the running current without blowing the fuse or tripping the circuit-breaker.

Where there are a number of motors to be started, as in a steel mill, it is a practical arrangement to provide a single transformer centrally located for each group of motors. The transformers should be supplied with an extra tap to give approximately 65 per cent line voltage; for three-phase motors five line wires would be required for the motor feeder circuit. Thus instead of a number of individual transformers, one transformer of large capacity is used and the starting apparatus is limited to a double-throw switch.

DISCUSSION ON "HIGH-POTENTIAL UNDERGROUND TRANSMISSION." NEW YORK OCTOBER 9, 1908.

(Subject to final revision for the Transactions.)

President Ferguson: The subject for discussion this evening, gentlemen, is not only interesting from a scientific standpoint, but is of great importance commercially, because of its possible influence upon the investment and methods of operation of our large lighting and power systems.

With the concentration of the production of electrical energy, with its attendant advantages of lower initial investment and of increased economy in operation, which seems to be the order of the day, there naturally follows the necessity for higher voltages. This demand is coming now not only from the country districts, where water power exists, but also from the more congested districts, such as our great cities where immense power houses have been established to supply not only the lighting, power, and railways of the cities themselves, but also of the suburban area for many miles around.

With the increase in values of property in the centers of our large cities, there comes a gradual expansion of the congested areas and with it, in the interest of public safety, a limitation in the use of overhead construction, especially for high-tension transmission lines, and we find ourselves facing the necessity of placing them underground.

Although a great deal of thought has been given to the subject of overhead high-tension transmission, there appears to be much less definitely known regarding high-tension underground transmission, possibly because the necessity for such knowledge has not previously existed. The possibilities of the future are so great and the trend of the times so marked that it appears the subject before us is a timely one, and it would seem very important that all operating companies supplying energy in bulk should investigate the matter thoroughly and give it much serious thought, since a knowledge of the conditions existing may result in great saving in investment and greater reliability in operation.

It is with the idea in view of bringing out such knowledge as may be available and impressing upon those interested the importance to them of assisting in the development of the work that the paper of the evening is presented to you.

Chas. H. Merz: Those of us who, by periodical visits to the states and by meeting American engineers when in England; have been able to keep in touch with American progress, have always been much impressed by the development and distribution of electrical energy in large cities in the States.

High-potential underground transmission has been used in such cases, but in the outlying districts it is perhaps not incorrect to say that underground transmission has only recently commenced to take the place of overhead transmission. The fact that a large proportion of the work hitherto has been in crowded and congested districts probably explains why a " draw-in " or " conduit " system has been, so far as the writer is aware, generally adopted for underground transmission in the United States in preference to the so-called " solid " system of laying cables, largely in vogue in England, or armored cables which are used almost exclusively on the Continent of Europe and also largely in England. The extension of underground transmission to outlying and less congested districts will probably result in considering the merits of these other two systems of laying transmission cables. It may be of interest to refer briefly to these different systems of laying cables and to some considerations affecting the layout of the cable network in such districts.

For congested districts, such as are met with in the centre of all large cities, the " duct " system is often the only practicable system because it is impossible to take up the streets frequently to lay further cables or to carry out repairs. Accessibility to the cables is, however, some would say, the only advantage of this system for, when laid in this way, the lead of the cables is probably more exposed to deterioration by electrolysis and chemical action than in either of the other two systems referred to above. Further, the system is expensive, especially if the manholes are really substantially constructed and if proper precautions are taken to prevent a fault on any one cable interfering with the other cables. It is also probable that the carrying capacity of the cables for a given section is somewhat less than with either of the other two systems, due to the bunching together of a large number of cables in a confined space and the presence of air between the cable and the duct, which must interfere with the transfer of heat from the cable. This latter point is influenced, of course, to a great extent by the number of ducts laid together and the arrangement of the ducts relatively to one another.

In the so-called " solid " system the cable is laid in an earthenware or wooden trough sufficiently large to allow, say 0.75 in. clearance all round the cable, which space is filled with bitumen, pitch or some similar substance. The trough is covered by 3 in. brick or tile.

According to the writer's experience, the solid system in either earthenware or wooden troughs is the cheapest of the three systems mentioned. In saying this it is assumed that armored cables are only permissible if the lead and armoring are effectively protected from moisture, etc. This necessitates not only a sufficient number of wrappings between the lead and the armor and outside the armor, but also effective impregnation of these coverings with some waterproof and insulating composition that will not crack when the cable is bent and which will retain its qualities. An efficiently armored cable costs, laid in the ground, in England from 5 per cent to 10 per cent more than a lead-covered cable laid on the solid system, but it would seem fair to say that an armored cable which is made and finished in the factory, where proper supervision is possible, should have a longer life than cables laid either on the solid system or drawn into ducts. The solid system has, however, proved an extremely efficient system in practice if care is taken in the composition of the material used for filling in the troughs. In this country, at any rate in outlying districts, it works out somewhat cheaper than a thoroughly well designed and manufactured armored cable, and it will no doubt continue to be largely used for such purposes.

Apart from the question of life of the lead, which, as far as present experience goes, is the same thing as life of the cable itself, the accessibility of the conduit system is of little or no advantage in outlying districts. In the writer's opinion it is of little advantage anywhere except in the most congested districts, for the following reasons:

1. It is more expensive, even if there are several ducts laid together and all ducts contain cables.
2. It is much more expensive in initial capital expenditure if spare ducts are laid.
3. Apart from the question of the greater security of supply, if mains are laid by different routes it does not pay in most cases to lay more than one cable by the same route; for it is obvious that if it is a question of supplying any given large area with power, the more the cables can be distributed along different routes the greater will be the number of power ,users that can be supplied without large expenditure on branch cables.

The question of the most economical arrangement of network is one that grows in importance as the area to be supplied increases. In congested districts where very large powers are dealt with from one sub-station situated within a relatively short distance of the generating station, it is frequently only possible to deal with the load by means of a radial system; that is, a system in which several mains, one or more of which are spare, run from the generating station to each sub-station. When, however, it comes to a question of distributing power over wide areas and in outlying districts, a radial system in which two or more cables, one of which is a spare, are laid by the same route to each sub-station, becomes very expensive and it is necessary to consider higher voltages and the use of so-called "ring mains." The use of high voltage also enables the most economical section of copper to be used. This economical section, according to the writer's experience, is in general somewhere between a 0.1 sq. in. and a 0.15 sq. in. cable (say 125,000 circular mils and 190,000 circular mils) for three-core cables; that is to say, it is more economical in first cost per kilowatt transmitted to transmit a certain amount of power by means of a cable of this section working at a sufficiently high pressure to enable it to carry the required quantity of power than by any other section or voltage. This, of course, arises solely on account of the fact that the smaller cable can be worked at a considerably higher current density for the same temperature rise. In congested districts where it is impossible to avoid the use of several cables on the same route to a sub-station fed direct from the generating station, it would be more economical, if armored cable or cables laid on the solid system were used, to lay a relatively large number of cables of the economical section rather than a smaller number of cables of the larger section working at the same voltage. If a conduit line be used, however, the number and size of cables are decided more by the total quantity of heat that a block of cables so laid can radiate than by any other consideration. For the sake of simplicity and to reduce losses and heat generated, the tendency will be to keep down the number of ducts and increase the section of the cable to 0.25 sq. in., or even more, with a corresponding increase in the total cost per kilowatt capacity. This is a further argument in favor of armored cable or cables laid solid.

If the network be made up of ring mains, the power may flow in either direction along any individual cable and it is not possible automatically to isolate a length of faulty cable by means of automatic cutouts of the ordinary overload and reverse-current type. According to the writer's experience, however, any difficulty in this direction can be got over by the use of some form of balanced relay system.* With this device faulty lengths of cable can be instantaneously cut out without any interference with the system or with synchronous plant running thereon, and without interrupting the supply to any consumer, however many sub-stations may be connected to the ring main, and, what is perhaps more important, there is no danger of a section of the system that is not faulty being also cut out.

This system has acted in such a satisfactory manner in actual practice that it is now being adopted largely both in this country and abroad for protecting all kinds of cable systems, whether laid out as ring mains or on the radial system.

Experience in the north of England shows that a 20,000-volt underground cable system may be installed with assurance that it will work well. In the counties of Northumberland and Durham there is now nearly 100 miles of such cable in use. The cables are three-core paper cables lead-covered and laid on the solid system in earthenware troughs; they are made to stand a test pressure of double the working pressure after laying and jointing, and short samples of the cable are specified to stand in the factory pressures of four times the working pressure after bending tests have been applied. There is also a very

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*For further details of this system see *Electrical Review* (London.) August 28th, 1908, and the *Elektrotechnische Zeitschrift*, dated 19th and 26th March, and 2nd April, 1908. (Paper by Herr Kuhlmann).

large mileage of 12,000-volt and 6,000-volt cable working in conjunction with the 20,000-volt system. In cables for extra-high-tension work the joints have generally been found to possess the lowest factor of safety, and it is well worth while devoting special attention to their design so as to provide ample margin in insulation to cover indifferent workmanship on the part of the jointer, and to make sure that after laying, the cable and not the joints would break down if a sufficiently high pressure were applied.

Spark-gaps are installed at each end of each cable length. At special points, such as where overhead lines join the cable system, water resistances are installed, thus providing a path for any surges that may occur under working conditions.

Experience has proved that there is no more trouble with such a system than with a 5,000-volt system. On several occasions consecutive lengths of 20,000-volt cable connected in series to form a single length of over 20 miles have been switched on, but in no case has there been any evidence at the spark-gaps or elsewhere of any excessive pressure. Cables directly connected to a large step-down transformer at the farther end have also been switched on without trouble. 11,000-volt overhead lines and cables have been working in series on the same network for some time without any dangerous surging. In some cases when faults have occurred in 20,000-volt joints, the automatic cut-outs have been found to isolate the fault before the compound in the joint has become thoroughly carbonized, and it has been necessary to close the switches and allow them to operate again several times before the localization tests could be applied. This treatment must subject the system to heavy rushes of current, but there has been no evidence of dangerous surging in the pressure which could not be taken care of by the spark-gaps, etc.

H. W. Fisher: Though the results of the tests given by the authors indicate what voltages cables may be subjected to under working conditions, yet I think it must be admitted that under other working conditions similar tests might have shown quite different results. It is, therefore, highly desirable that other operating companies should make similar tests covering a long period of time and present the results before the Institute. When this is done a better idea of the conditions producing maximum voltage stress can be obtained.

The authors have not specified clearly what they mean by double working voltage, for with a grounded neutral the voltage to ground on the 20,000-volt lines would be 11,550 volts. This doubt impels me to ask if the voltage applied between conductors and ground is $2 \times 11550 = 23100$ volts, and that between conductors, 40,000 volts? If these are the voltages applied, the test to ground is not sufficient, because in some cases the spark-gap method gave over 25,000 volts. I would suggest two and one-half times the working voltage as a figure that is more in keeping with tests made on other large installations of cables in New York City and elsewhere, as it is to the interest of both manufacturer and operator to have the assurance that the cables in question can withstand for five minutes two and one-half times the working voltage without failure or injury to the dielectric.

I presume that the 11,000 volts mentioned several times at the bottom of Fig. 4 should really be 11,550 volts, the electromotive force to ground on a 20,000-volt circuit with the neutral grounded.

With cables operating at extremely high voltages, limitations in duct size, test of cable, and the possibility that impulsive rises of voltage are proportionally less than with lower voltages, may make a double working voltage test sufficient.

Statements made in the paper convey the impression that a good insulating compound is the all-important feature of cable joints. I believe that the method of joint construction is the first and most important consideration; after this work is done well, the use of any good insulating compound of proved merit with fairly high melting point, a compound which does not in compounding with the insulation of the cables themselves form an inferior mixture, will insure perfect joints. It should be remembered that the insulating of the individual conductors is a matter which almost necessarily and unavoidably varies with the workmen. I have found that by standardizing joint-making by the use of properly prepared paper tubes of suitable size and composition, I am able to insure at least the necessary minimum thickness of insulation at all points. In my experience this plan works out better than where the thickness and tension under which insulating tapes are applied by individual workmen are left to individual judgment. I understand that such tubes were used on the cables referred to by the authors.

In one of the foot-notes I see that the voltage rise was 30 per cent more when the neutral was grounded through 2.6 ohms. Was this increase due to a distortion of the electromotive force wave curve by increasing the ratio of maximum to mean effective volts? I have obtained this effect, but only when the series resistance was high.

It is interesting to note that the voltage did not rise when the circuit was opened. This I suppose was due to the fact that oil circuit-breakers open at or near the zero part of the electromotive force wave. I have frequently obtained rises of voltage by opening a switch which made an air arc when operated.

The authors say that "asphaltum troughs certainly guard against electrolysis." I must take exception to this statement, because the worst cases of electrolysis I have known were on cables laid in troughs filled with asphaltum. If a cable could be perfectly protected from moisture by asphaltum, I admit that electrolysis would not occur, but this is scarcely possible, and at the moist spots the electrolysis is greatly accentuated causing pit holes in the lead. I know of cases where thousands of feet of cable laid in asphalt troughs were completely destroyed by electrolysis. While it may seem desirable to insulate the lead covers of cables, it must be remembered that when these cables are of the single-conductor type and carry alternating currents these induced voltages between the lead covers may be considerable. I have obtained from 15 to 30 volts per 1000 ft. with an ordinary lead-covered cable, and in the case of a steel-wire armored cable the lead volts per 1000 ft. were 100. The lead volts per 1000 ft. on the same kind of cable armored with two wraps of steel tape were 350. From this it is evident that at least in the case of armored cables, the armor and lead should be connected frequently, especially as the lead current may be as high as 80 per cent of the conductor current, and this is of sufficient magnitude to cause destructive alternating-current electrolytic action if the current be concentrated at isolated points. Fortunately, in practice the sheath of armored cables is generally continuously grounded.

The thickness of insulation on the 9000-volt cables is given but it is not given in the case of the 20,000-volt cable.

H. G. Stott: I recently passed through Buffalo, and I was interested to inquire about the history of certain cables which I put down there in 1891. They were rubber-covered cables, $\frac{4}{32}$ in. rubber, with lead jacket, and put down to carry 60-light arc circuits, having approximately 3000 volts pressure. I found that they are using these same cables to carry 100-light enclosed arc lamp circuits of 7500 volts. As these cables are now 17 years old, the permanency of the investment seems to be very gratifying. Other cables, I think 0000 copper size, which were purchased and put down at the same time, 17 years ago, for use on 1100 volts, having also $\frac{4}{32}$ in. rubber insulation with lead jacket, are to-day carrying 2500 volts, and are said to be the best cables they have.

Referring to Table I, the first column shows the year, and the second the miles of cable. It will be noticed that after the first 2 years the miles of cable are a little more than doubled. The first 2 years apply to the cables of the Manhattan Elevated Railway, and subsequently they apply, from 1904 on, to the subway cables also. For the last 3 years there have been over 350 miles of 11000-volt cables in service. Following along the first year there will be found a classification of the troubles, which shows a total of 7 burn-outs, due to various causes, one of which was due to a surge. The last column, excluding external causes and damages due to crowbars, etc., gives the number of burn-outs per 100 miles of cable per annum. In the first year there was considerable trouble with the joints, but there was only one fault in 122 miles of cable, and there were only 4.91 burn-outs per 100 miles, due to all internal causes.

In the second year, 1903, there were four breakdowns due to surges. Dr. Steinmetz has expressed an opinion on what probably took place,* and concluded that these surges probably caused a rise of potential of 120,000 volts, so that an 11,000-volt cable can not be blamed for breaking down under these conditions.

TABLE I.

HIGH-TENSION CABLE BREAKDOWN SUMMARY.

JAN. 1902 TO OCT. 1908.

11,000 VOLTS.

Year	Miles of cable	In joint	In bend	In cable		External causes	Total	Excluding external causes and surges per year per hundred miles
				Faults	Surges			
1902	122	3	2	1	1		7	4.91
1903	144	2		1	4	1	8	2.09
1904	330	1		1		1	3	0.61
1905	351		1	2			3	0.85
1906	353	3		3	1	4	11	1.70
1907	353	1				5	6	0.28
1908	368	1				4	5	0.28
Total		11	3	8	6	15	43	

NOTE.—

External Causes { Mechanical injury.
Steam leaks.
Armor burns from other cables.

The number of burn-outs per 100 miles of cable per annum has fallen during the last 2 years to 0.28, or practically one fault per 400 miles of cable per year. That is a reassuring record; when our overhead transmission lines can show anything like it, we can look forward to reliable long-distance transmission.

Fig. 1 is an oscillograph record taken, which shows the turbine generator running on the circuit. No. I is the voltage on phases 1 to 2, 10,000 volts; No. II is No. I phase to neutral, 5780 volts; No. III is neutral to ground.

Fig. 2 shows the same machine simply switched on to 38.3 miles of cable. This is rather an interesting record. No. 1 is the potential wave, No. II is charging current to cable phase 1, and No. III charging current to cables through neutral. There is a very pronounced ninth harmonic; it amounts probably to seven per cent of the fundamental. That was a revelation, as we had no idea that any such harmonic as that existed, and we are going to make further investigations. I think it also illustrates the point that further investigations on underground cables will probably yield great rewards for our trouble.

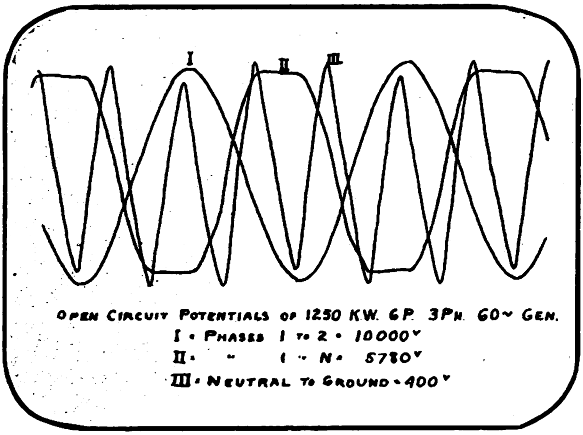


Fig. 1

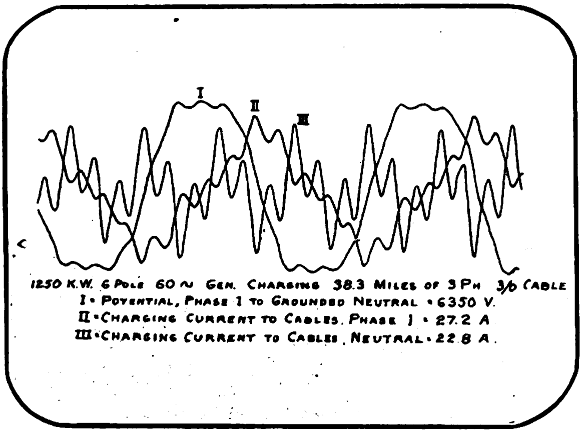


Fig. 2

Mr. Merz is a distinguished engineer of very wide experience, but I think that we should apply his conclusions with great caution. Two systems, absolutely similar as to cables, capacities, inductance, etc., but having widely different amounts of power connected, may act in entirely different ways. A system absolutely harmless with perhaps a couple of thousand kilowatts connected to it, may become subject to the most destructive surges and phenomena of all kinds when 100,000 kilowatts are connected to it. In the particular case of the Interborough system, it is possible to develop more than 300,000 kw. on short-circuits between stations. In Mr. Merz's system there are comparatively small and scattered stations, as I understand, so in our American plants there is an entirely different set of conditions.

An apparatus which is going to help out materially in the development of large power plants is the induction type of generator. We cannot, I believe, go on adding indefinitely to the capacity of synchronous generators in one plant. We will soon reach a point where the short-circuit current will be so great that it will be absolutely impossible to take care of it by any automatic apparatus. We all know that in the case of a bad short-circuit on a large system the time-element relays and reverse-current relays fail to act selectively, and everything goes out. With the induction generator, however, we can add on to our present plants indefinitely without increasing the short-circuit current, as the induction generator has the peculiar characteristic of practically ceasing to generate under short-circuit conditions.

E. J. Berg: This paper gives a clue to the probable maximum voltage for high-potential cables. This clue is more discernable when the results obtained by the authors are compared with those obtained in similar tests recently made by Mr. W. F. Wells and myself on the Brooklyn Edison Company's system. In these tests the voltage was 6,000 instead of 9,000, and the neutral was not grounded. We also found from spark-gap indications that under apparently normal conditions double voltage existed at times. These abnormal voltages occurred relatively seldom, perhaps once in a week, or once in two weeks, whereas with the 9,000-volt cables in the Chicago system these abnormal voltages took place every day; and in the case of the 20,000-volt system they found them much more frequently. From this it seems reasonable to conclude that the difficulties due to abnormal voltages will increase with the cable voltage, as should indeed be expected, since a large part of the available energy is stored electrostatically and is proportional to the square of the voltage. Beyond question, commercially a 20,000-volt cable system seems perfectly practicable, the question is how much higher can the pressure be raised.

At the St. Louis International Congress in 1904 Mr. Jona read a paper on cables, discussing the dielectric strength of various insulating compounds and insulators, in general. If I remember correctly, he stated that the maximum permissible potential gradient at the surface of the conductor, using rubber as insulator, was 300,000 volts per inch. Assuming that to be correct, it is possible to calculate the limiting voltage for a given size conductor. Calculations show that it would not be practicable to use small conductors at 20,000 volts and above. At 40,000 volts quite large insulators would have to be used even if the insulation were of the very best.

With large conductors, it would be hardly practicable to make three-conductor cables, they would be unwieldy; consequently single-conductor cables would be used. With single-conductor cables, difficulties may be anticipated, since there is considerable losses in the lead if the lead is grounded, and if the lead is insulated it is subjected to considerable voltages. However, these voltages are proportional to the current, and the losses to the square of the current, and the current will be relatively small at 40,000 volts, so that these difficulties may not be serious.

The authors mention the large current taken by transformers in switching. The oscillograms show six times normal full-load current; that is, perhaps sixty to one hundred times the normal exciting current or the current which would flow after a second or two. This abnormal current depends upon the magnetic condition of the transformer and the phase of the impressed electromotive force at the time the switch is closed. In general, the lower the saturation under normal operation the less instantaneous current. If the density of the iron in the transformer were 65,000 lines per square inch, double voltage could be applied without saturating the iron. Thus such transformers would not be saturated when closed to a circuit of normal voltage even if the phase relation of the electromotive force were most unfavorable, assuming that the residual magnetism were small. With such transformers the maximum current would no doubt be less than full-load current. They would, however, require from 30 to 50 per cent more iron, and would therefore cost more. This construction would not be warranted unless great advantages were gained. These advantages would be: first, small current, which often is of little value; secondly, small mechanical stresses on winding which may be of advantage. So far I have been unable to locate any large stresses, but they undoubtedly exist.

Wallace S. Clark: The authors say that in a grounded system—I presume they mean star-connected—with the neutral grounded, the burn-outs take place to ground. That is not necessarily so. It happened in this case because: first, the insulation to ground is less than that between conductors; secondly, the cable is paper-insulated, and the usual cause of failure of paper-insulated cable is some injury to the lead. It is probable that the burn-out would go to earth, but if the cable had the same thickness of insulation to lead that it had between conductors, it is possible that surges would also have caused some rise of potential between phases, and might have caused a burn-out between conductors.

I do not think that the putting of high voltage periodically on cables for the purposes of tests does the cable any good; it does not show anything, and it is no assurance that the cable tested that way will not burn out the next day or the next hour. Insulation tests are perhaps a little better made periodically. Furthermore, with the present tendency to make paper cables with very low insulation resistance, it is rather difficult to get good results from such tests. There is, however, one form of inspection which is greatly needed, the inspection for electrolysis.

If the same amount of money were invested in watching for electrolysis, as in periodic high-tension insulation testing, just as many burn-outs would probably be avoided.

That with a star-connected circuit neutral grounded about seven-tenths of the insulation between conductors is all that is needed to ground, seems to be more of a theory than a fact, because the potential rise noted in this paper seemed to be to ground, to be apparently double the working potential between conductors, and a good deal more than double the working potential to ground. The overcoming of this condition would really be of tremendous economical importance, because it would mean a very much cheaper cable for a given service.

There is one feature in practically all types of cable installations that has not been referred to; that is, the cable that is tested for five minutes at two and one-half times the working pressure will easily stand for five seconds four times the working pressure. That the puncture is a factor, not only of the pressure, but of the length of time the pressure is applied, has been a boon to every cable installation in this country. Several years ago I made some tests to verify this. A few days ago, after reading Messrs. Junkersfeld and Schweitzer's paper I made similar tests, and these gave almost exactly the same results as those formerly obtained.

From the cable manufacturers' standpoint there is no hesitation about using 25,000 volts. But I do not think that it is practicable with any of the forms of insulation in use at present to make very small conductors for 25,000 volts satisfactorily. Furthermore, 25,000- and the 20,000-volt cables that are in use in this country are really working at a less factor of safety than most of the 11,000-volt cables.

I understand that the thickness of insulation in thousandths of an inch between conductors on the Chicago 9,000-volt cables is about 44, and on the 20,000 volt cables about 28 per 1000 volts. It is undoubtedly true that the 20,000-volt cables are made with more care, and probably with a higher dielectric strength in the insulating material, but I doubt if that is enough to make up for so great a difference in thickness of insulation per 1000 volts, so it must be acknowledged that these cables are worked at a less factor of safety. This condition may be a justifiable one, because these cables are less important to the system than the 9,000-volt cables; if this is not so then the 9,000-volt cables have altogether too much insulation on them.

In the matter of cable economics, assume that there are two cables, a 25,000-volt cable and an 11,000-volt cable and that they will last almost exactly the same length of time. Then it is necessary to write off more money per year depreciation on the 25,000-volt cable than on the 11,000-volt cable because the copper for which scrap value can be obtained is the same. Assuming the scrap value of the copper at 15c. per pound for a 4/0, 11,000-volt paper cable, then there will be written off for whatever may seem to be the life of the cable, 66c. a foot on the 11,000-volt cables, and on the 25,000-volt cable about $1.19 a foot.

There are some other cables besides the ones mentioned by Mr. Stott which are running along peacefully under 11,000 volts pressure, and are just about as good as when they were installed in 1898. I think they are the oldest 11,000-volt cables in the country. Unfortunately these cables, as well as the cables Mr. Stott mentioned, are rubber-insulated and do not depend entirely on the lead covers. Just how long a lead-covered paper cable will survive is still undecided.

Alex Dow: In Detroit there are two cables operating regularly at 23,000 volts. Each cable is 39,075 ft. long. The cable conductor is 19-strand, equal to No. 2 B. & S. The insulation is $\frac{2}{32}$ in. rubber and $\frac{6}{32}$ in. of varnished cambric on each conductor, and $\frac{3}{32}$ in. varnished cambric over all, and $\frac{3}{32}$ lead sheathing. The lead sheath is sectionalized at every second manhole, between 700 and 800 ft., in order to prevent the travel along the lead sheath of stray railway return current. Each of these 700- and 800-ft. lengths of lead sheath is solidly connected to earth. One of these cables has been in service for 13 months. It is not the older of the two cables, but it is that which has the most continuous and useful history. It went into service September 4, 1907. Since that time it has broken down six times. One of these breakdowns was obviously due to high temperature from a nearby steam heating pipe. The other five are not attributable to any known cause; four of the breakdowns were in the cable itself, including the one due to the known cause; two of them were in joints. There were four to earth, and two between phases. Adding to this the experience had with the second cable, after it was rejoined, I may say that the total breakdowns were twelve, seven of which were in the joints and five in the cable. Seven were short circuits and five to earth. So that nothing seems to be proved.

The most notable observation is that the faults occur in the middle third of the cable, and are not accompanied by any great disturbances at the terminals. This seems to confirm the observation made by Messrs. Junkersfeld and Schweitzer, that such disturbances do not travel the entire length of the cable, but may spend their energy in one part thereof. Our conception which we will attempt to confirm or disprove by experiment, is that in a cable of that length, working at that frequency, connected in the way in which that is connected, the tendency is for such disturbances to attain their maximum in the middle third of the cable. A desirable precaution would be to cut the cable in the middle, looping it into a sub-station in that neighborhood which is available, and there connect it to electrolytic static dischargers. This will be done, and the action following thereon may be of interest to us, or it may not.

The joints of the first cable were originally insulated according to instructions received from the cable manufacturers by applying a straight wrapping of the varnished cambric tape. The three-conductor joints were wrapped over all and the sleeve filled with a compound. It was obvious to us that the compound used could not possibly penetrate between the layers of tape, and that it was not at all likely to penetrate thoroughly all the larger interstices between conductors. It did not, in fact. The joints broke down continuously from the time the cable was put in service. We stopped using it during the day, but operated it at 4600 volts during evenings as a reserve cable. During the day we made over again the one hundred and twenty-five joints. In the new making up of the joints we restored the rubber as nearly as might be, with the usual vulcanizing tape. We also restored the varnished cambric insulation, thoroughly painting each lap of tape with a non-drying varnish of the same kind as that used in making the cable. The result was satisfactory. The joints, placed on test in comparison with the original joints, showed that they could remain intact under a prolonged test of 30,000 volts. The original joints always broke down within a week or two. The cable put into service with these new joints proved as satisfactory as the other cable which had such joints to begin with.

Our conclusion, in addition to the one already given, is as follows. It is essential that the insulation of joints shall be solid and not include air, as air in the lapping sooner or later causes the joint to break down.

On emergency work and repairs made in a hurry we have used rubber and paper and paraffin. We admit that paraffin is not entirely satisfactory, but we have never had a breakdown which could be attributed to moisture in a paraffin joint, and there is no doubt that thoroughly boiled out paraffin has no air left in it. Whatever of shrinkage there is in the paraffin, is to all intents and purposes followed up and the joint is homogeneous.

Another conclusion is for a higher factor of safety to earth. It will be noticed that the over-all insulation is $\frac{3}{32}$ in. which is theoretically correct, with the grounded neutral. We think that there should be a higher margin of safety, and have adopted it on a third cable which is now going in.

Mr. Merz wants to put his cables down solid in asphaltum so that they will not be attacked by electrolysis. That is quite a common and doubtless a proper practice in England, but it is questionable whether it is worth while in America. Of late years we have adopted the practice of laying pavements on water-proof foundations. In almost all American cities, with a few exceptions, like New Orleans, the soil is under drained, so that the soil in which the conduits are laid is reasonably dry. Any one who has had experience with cables has noticed that in a street in which electrolysis was frequent, and failure of lead coverings common, the trouble has ceased as soon as the street was paved with a water-proof pavement. It is obvious that there is no electrolysis in dry soil, but perhaps there is no dry soil in England.

The system referred to by Mr. Merz is along the line of a distribution system, as distinguished from a transmission system. In none of our large systems, except perhaps the central districts of New York and Chicago, would the comments of Mr. Merz be quite applicable. The cables in Detroit and in most American cities go into sub-stations, from which the distribution is by overhead lines. Where cable distribution is required it is under conditions which call for radial distribution. Circular distribution, while occasionally called for, is not frequent. Therefore the comparison of English and American cable methods is not direct, but can only be indirect.

Warren Partridge: The experience of the Public Service Corporation of New Jersey with high-potential underground transmission when reduced to burn-outs per mile of cable per year has been considerably better than the 20,000-volt experience in Chicago, as reported by Messrs. Junkersfeld and Schweitzer, but when compared with the Chicago 9000-volt system, the results have been very much worse. The exact facts will be given, however, with the hope that they may help engineers of cable systems to tend toward the straight and narrow path where cables never puncture nor picks break through.

The essential facts of the Public Service system are as follows:

Marion Plant with 10,000 kw. in 25-cycle turbine units
and 6,000 kw. in 60-cycle " "
Coal Street plant with 9,000 kw. in 25-cycle engine units
City Dock " " 5,950 kw. in 60-cycle " "
and 3,000 kw. in 60-cycle turbine unit

The City Dock plant generates 2400 volts two phase and connects to the transmission system through 3000 kw. in transformers connected three-phase—two-phase Scott system. With this exception all generators are three-phase, 13,200 volts star wound. The neutral is not grounded.

Connected to the 13,200-volt bus-bars at Marion, Coal Street, and City Dock are twenty-one underground feeders, aggregating 81 miles of cable and two overhead feeders aggregating 65 miles of line. These cables and overhead lines feed nine 60-cycle sub-stations in which the greater part of the apparatus is composed of step-down transformers, and twelve 25-cycle sub-stations in which there are synchronous converters. The 60- and 25-cycle systems are independent except that some cables can be used on either service.

One cable is No. 4, four cables No. 1, while the remaining sixteen cables are 00. All are three-conductor, paper-insulated $\frac{7}{32}$ in. over each conductor and $\frac{7}{32}$ in. over all, giving 0.437 in. between conductors and between each conductor and ground. The cable sheath is $\frac{1}{8}$ in. lead and the majority of joint sleeves are paraffin filled, compound having been used on a few of the cables. The conduits are part fibre duct and part tile duct.

The record of cable troubles from January 1, 1905 to October 1, 1908, a period of 3.75 years, is as follows: breakdowns, in joints, 11; from external causes, 16; in the cables, 25; a total of 52. The total number of cable-mile-years is 255. Therefore the actual cable breakdowns not accounted for by external causes or by defective installation is approximately 0.1 per mile of cable per year.

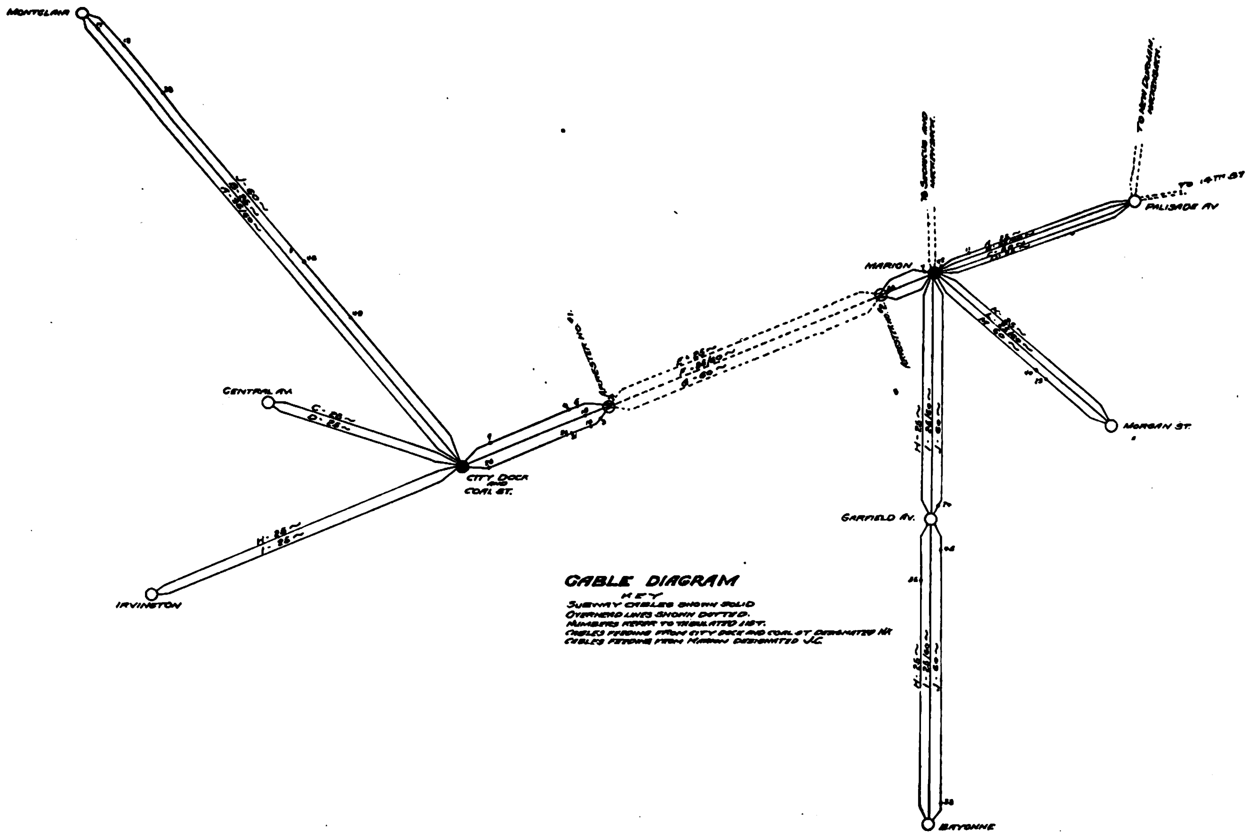
Estimating from the data given by Messrs. Junkersfeld and Schweitzer, the results in Chicago on the 11,000-volt system are approximately 0.02 and on the 20,000-volt system 0.14 breakdowns per mile of cable per year.

The data given by Mr. Rhodes last year for the Interborough Rapid Transit Company 11,000-volt system showed about the same results as the Chicago 9000-volt system, while Mr. Torchio's figures for the New York Edison were, I think, even better.

Analyzing the breakdowns by cables, shows that eleven of the twenty-one cables have had no trouble whatever, that five cables have had one each, two cables two each, and that the remaining sixteen breaks have occurred on four cables.

These four cables stand out by themselves as follows: two of them are tie lines between Marion and the Coal Street and City Dock plants. One is used exclusively for 25-cycle and one exclusively for 60-cycle service. Both cables run from Marion in conduits for 2500 ft., then as armored submarines for 1000 ft., then as overhead lines for 16,000 ft., then in conduits 11,000 ft. and again as armored submarines 1000 ft. into the Coal Street and City Dock plants. The tie lines have, therefore, peculiar physical characteristics. Their use in actual operation differs also from the other straight feeder lines, for as ties between generating plants a considerable amount of synchronizing is done over them.

It is not the practice to operate the plants in parallel over these lines; they are, however, often synchronized in order to transfer load from one station to the other without service interruptions. We know that some of the breakdowns over


MONTCLAIR
J. 60 ~
CENTRAL AV.
C. 25 ~
D. 25 ~
IRVINGTON
H. 25 ~
I. 25 ~
CITY DOCK AND COAL ST.
F. 25 ~
G. 60 ~
MARION
TO 14TH ST
PALISADE AV
MORGAN ST.
H. 25 ~
J. 60 ~
GARFIELD AV.
BAYONNE

CABLE DIAGRAM
KEY
SUBWAY CABLES SHOWN SOLID
OVERHEAD LINES SHOWN DOTTED.
NUMBERS REFER TO TABULATED LIST.
CABLES FEEDING FROM CITY DOCK AND COAL ST. DESIGNATED N.K.
CABLES FEEDING FROM MARION DESIGNATED J.C.

these lines have been due to synchronizing or rather to non-synchronizing and believe that others have been due to this same cause even when it was impossible to trace the sequence of events.

The other two lines that have a large number of burn-outs are both long lines, seven miles each, are both operated exclusively on 60-cycle service, and are both smaller than the standard 00 cable, being No. 4 and No. 1 respectively. One feeds from the Marion bus-bar and one from City Dock bus-bar. What the relation is between the above characteristics and the resulting burn-outs is hard to determine. Spark-gap and oscillograph records during different switching operations would undoubtedly throw some light on the subject and will be made later in connection with proposed installation of electrolytic dischargers.

Voltage surges of more or less severity have taken place a number of times on the system, as indicated not only by the cable punctures but by the wrecking of many sets of static dischargers and lightning-arresters.

In spite of all difficulties experienced we agree with the authors of this paper, that cable systems are fully as reliable as other elements in the electric power system. Our records for a period of three years show that cable breakdowns caused but 7 per cent of all the interruptions to service and that the duration of time of cable interruptions was no longer than the average for interruptions from other causes.

A quick summary of the essential differences between the Chicago system and the Public Service system might be made as follows:

1. Chicago, 9000 volts. Public Service 13,200 volts.

This condition is at once much more severe, being a voltage increase of nearly 50 per cent, and assuming a possible surge voltage of double potential would give a possible maximum of 26,400 against 18,000.

2. Chicago, essentially all underground feeders.

Public Service, a considerable amount of overhead lines operated in conjunction with the cable system.

3. Chicago, thickness of insulation per 1000 volts 0.44 inch between conductors and 0.38 in. between conductors and ground.

Public Service, thickness of insulation per 1000 volts 0.33 in. between conductors and between conductors and ground.

However, as thickness of insulation is not a direct function of voltage it is probable that the factor of safety of the two insulations is not radically different.

I would like to inquire what thickness of insulation is used on the 20,000-volt cables at Chicago, and whether ducts larger than standard 3 in. have been employed to carry these cables?

4. Chicago, neutral grounded.

Public Service, neutral not grounded.

There may be other differences between the two systems which would be evident to one more familiar with that of the Chicago system.

The above comparison is made, in order to give, if possible, some clue to the reasons behind the greater percentage of breakdowns that have occurred on the Public Service system.

Breakdowns
13,200-volt cable system

No.	Date	Cable	External injury	Joints	Break-downs
1	5- 7-05	Nk. B	..	1	..
2	7-16-05	" E	..	1	..
3	9-16-05	" G	..	..	1
4	10-22-05	" E	..	..	1
5	11-17-05	" E	..	..	1
6	12- 2-05	J. C. A	1	..	..
7	5- 4-06	" E	..	..	1
8	5- 7-06	Nk. B	1	..	..
9	7- 6-06	" E	..	..	1
10	7- 6-06	J. C. A	1	..	..
11	7-15-06	" A	..	..	1
12	7-17-06	Nk. J	..	..	1
13	7-19-06	" A	..	1	..
14	9-25-06	" E	..	..	1
15	9-29-06	" F	..	..	1
16	10-10-06	" G	..	..	1
17	10-20-06	" B	..	..	1
18	11- 4-06	" E	1	..	..
19	11- 4-06	" F	1	..	..
20	1- 5-07	" G	..	..	1
21	1- 7-07	" G	..	..	1
22	3-15-07	" B	..	1	..
23	3-27-07	J. C. M	..	..	1
24	3-27-07	" J	..	..	1
25	4-24-07	" H	1	..	..
26	5- 4-07	Nk. G	..	..	1
27	6-17-07	" J	..	1	..
28	6-17-07	" G	..	1	..
29	6-17-07	" G	..	1	..
30	8-24-07	" E	1	..	..
31	8-25-07	J. C. M	1	..	..
32	8-29-07	" L	1	..	..
33	8-30-07	Nk. J	..	..	1
34	9-16-07	J. C. K	1	..	..
35	9-21-07	" M	..	1	..
36	10- 5-07	" H	..	..	1
37	10-20-07	" D	1	..	..
38	1-20-08	" J	..	..	1
39	2-18-08	" H	..	1	..
40	4-22-08	" M	..	..	1
41	5-26-08	" L	1	..	..
42	7- 1-08	" A	..	..	1
43	7-14-08	Nk. G	1	..	..
44	8-16-08	J. C. C	1	..	..
45	8-20-08	" J	..	..	1
46	8-21-08	Nk. J	1	..	..
47	8-25-08	J. C. C	1	..	..
48	8-25-08	Nk. J	..	..	1
49	9-12-08	" J	..	..	1
50	9-13-08	J. C. F	..	..	1
51	9-13-08	" G	..	1	..
52	9-16-08	" G	..	1	..
	Totals.........	....	16	11	25

Similar comparisons might be made with the systems of the New York Interborough and the New York Edison, with this difference: the New York Edison system is 6600 volts and the neutral is not grounded, while the Interborough is 11,000 volts and the neutral is grounded through resistance.

The fact that the Public Service voltage is higher than any of the above systems seems the most obvious explanation of the results, and the fact that the Chicago 20,000-volt figures are not as good as those from their 9000-volt system further bears out this conclusion; the answer being that as the voltage has been raised, the general factor of safety of cables, switching devices, protective apparatus, and the personal element of the operators, has lagged somewhat behind.

E. E. F. Creighton: All experience confirms the authors' statement that with rapidly growing systems the destructive effects and danger of breakdowns tend constantly to increase. There is a tendency to danger from another source which may be distinguished from that of mere increase of kilowatt capacity and mileage of cable. This danger is involved apparently in accidental coincidence of capacity and inductance with a surge frequency of harmonic when an accidental arcing ground takes place. There is a third condition, mentioned by the authors namely, rises of potential when the circuit is operating normally. By normal operation is meant the absence of arcs between any phase and ground, or an isolated conductor. There is still a lack of complete experimental data, but I feel convinced that these three conditions outlined are quite distinct, although they may all exist simultaneously. Reviewing these conditions.

1. The troubles resulting from excessive power. A short-circuit of great power stores up electromagnetism which, if suddenly destroyed, produces excessive potentials. It is generally believed that arcs of thousands of amperes of alternating current have a tendency suddenly to interrupt the current. Incidentally, the excessive mechanical strains have a tendency to crack or otherwise injure insulation, combined with an accidental arcing ground.

2. The second condition is the old meace, resonance. That a mere increase in power and cable mileage may have less to do with the production of transient abnormal potentials was proved by some tests made by the writer in association with Mr. S. D. Sprong. The conditions of a cable system were such that the instantaneous value of the surges could be recorded with an oscillograph. Tests were made first with one cable, then we were surprised to find that the surges were less when a second cable was connected to the same bus-bar. When a third cable was added, however, the surges were again aggravated and increased in severity for every successive addition. The detailed results of these tests we hope to present later, when the work will be more complete.

3. The surges not generated by an arcing ground which travels around a circuit are surrounded with mystery. They are not directly connected with switching or accidental conditions, and by observation they frequently produce higher potentials on the system than accidental arcing grounds. The probable source of the oscillations is the arcs on the low-voltage circuit.

In some tests made several years ago on the system of the Detroit Edison Company operating under normal conditions we found potentials of 125 per cent every few seconds, potentials of 150 per cent to 175 per cent every few minutes, and potentials of over 200 per cent twice in one day.

It is not possible commercially to insulate every conductor from its adjacent conductor sufficiently to carry the maximum potential strains of the system. For example, a turn of a transformer normally carrying 10 volts cannot always be insulated to carry the line potential of say 10,000 volts, yet it is possible to get such a potential there. Fortunately such potential differences do not occur frequently in actual practice, and on the end-turns, where they usually appear, the insulation is exceptionally reinforced.

L. T. Robinson: In view of the reference to some limitations of the oscillograph used by Messrs. Junkersfeld and Schweitzer, and the accompanying statement that "For all practical purposes the apparatus is quite satisfactory," I do not feel that the remarks are entirely justified.

In reference to the free periodicity of the vibrators, it is quite possible to produce moving systems in which the current passes through the strips having a frequency of nearly double that which was used or, roughly, 10,000. However, this is accomplished at such a sacrifice of strength and size in the moving parts, that it is not desirable for industrial use. Further, with few exceptions any investigation that requires a frequency in the vibrators of over six or seven thousand would require a frequency of an entirely different order.

The authors say that the vibrators cannot be made absolutely dead beat. I feel that this must be due to a misunderstanding of what can readily be accomplished, as the tests on vibrators shown in Figs. 1 *a* and *b*, indicate over-damping in some instances.

It is true that the self-induction of the vibrator circuit can never be entirely nil. This is no less true of any circuit which can be arranged. The inductance of the vibrators themselves is so small in comparison with any arrangement of conductors which can be used to connect it to the circuit under test, that this limitation, if it has any real significance, does not relate specifically to the oscillograph. In fact it is quite possible that the vibrator itself, due to the action of the moving strips in the magnetic field, could be represented as a capacity rather than as an inductance; that is, the current through this circuit as far as the vibrator only is considered may possibly be leading by an imperceptible amount.

The sensitiveness of the apparatus can be improved somewhat, but if a different class of problems entirely are to be attacked a sensibility of an entirely different order is required, and the small amount which can be gained by sacrificing strength and dimensions of moving parts is not worth while. The limited time-interval of application, I believe, should not be considered a

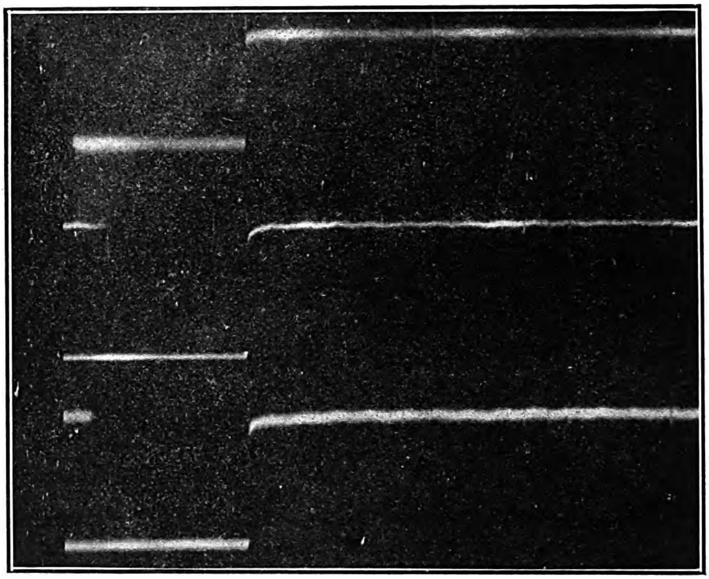


FIG. 1.—*a*. Overdamping. ————>
Three vibrators using separate zero lines.

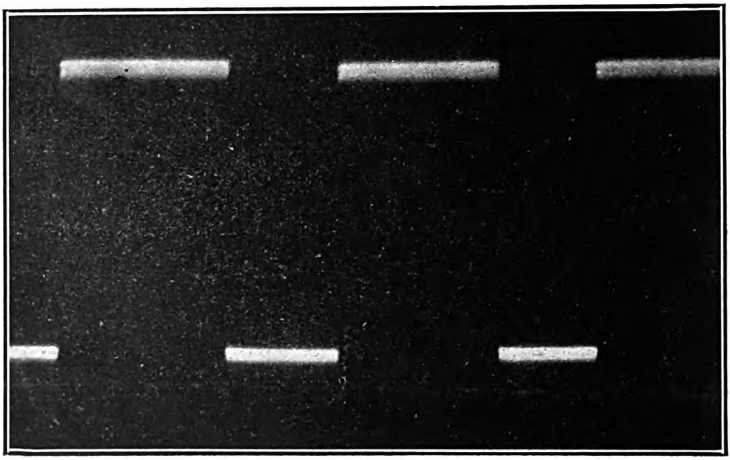


FIG. 1.—*b*. Critical damping. Single vibrator. ————>

The time scale is such that the portions of records shown in *a* and *b* correspond to about 1.25 sec.

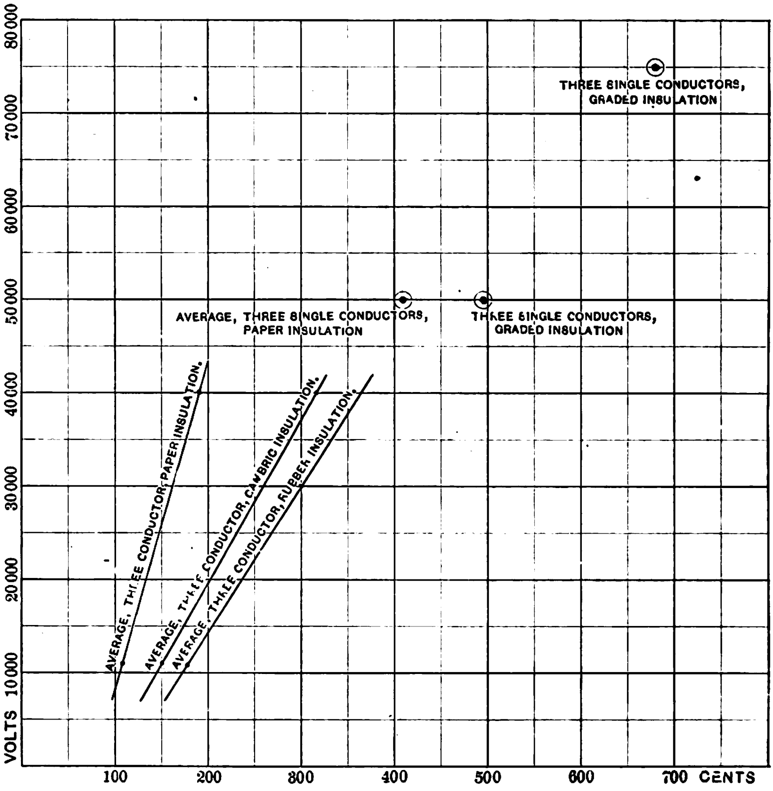
shortcoming at all. To meet conditions of continuous application for comparatively long intervals, special devices for moving a film to receive the image have been devised. They could easily be made and would, undoubtedly, be successful. The trouble here is not one relating to mechanical or electrical details, but to the fact that to operate a film continuously, of the usual width, and at speeds ordinarily employed, would cost about $500 per hour, a prohibitive amount.

I believe the reason why no spark-gap discharges were obtained simultaneously with the taking of an oscillogram was due to the fact that the potential rises represent a very small amount of energy. When the oscillograph is connected the discharge passes through it, thus preventing any rise of potential, and fails to record on the film, either because of its very short duration, or the very small current in the instrument at the time.

Henry Floy: The experience with 20,000 volts here cited and the testimony that could be adduced regarding 25,000-volt cables show that even at these higher voltages such cable is reliable. Above these potentials, we have, as far as I know, no commercial installations in this country. The authors have touched on the questions as to whether it is practicable, and whether commercial conditions will require in the near future, the use of cables at higher potentials. Some figuring has been done, particularly by engineers in England, tending to demonstrate that 25,000 volts is as high a potential as it will commercially and financially pay to use in connection with cables, indicating that if higher voltages are attempted the cost of the cables will be so great as to make preferable the installation of cables in greater number operating at lower potentials.

With reference to high-tension cables for alternating-current service, the manufacturing companies are ahead of the operating conditions; that is to say, the manufacturing companies have for years been ready to furnish cables for higher potentials than the operating companies were ready to use. For instance, at present it is possible to obtain, a cable designed for 75,000-volt operation, tested for a much higher potential; but I do not suppose that any one is quite ready to install a 75,000-volt underground distributing system, although possibly such cables could advantageously be used at the end of an aerial line or under water where special conditions require special construction.

As regards the commercial, financial, and practical use of higher tension cables; that is, those designed for potentials above 25,000 volts, the speaker has been investigating this matter lately and has obtained within the last two weeks from a number of the largest cable manufacturers, prices on high-tension cables for 11,000-volt, 25,000-volt, 35,000-volt and 50,000-volt service, having conductors of No. 0000 B. & S. gauge; also, not so recently, quotation on 75,000-volt cable of 50 square mm. conductivity. The 50,000- and 75,000-volt cables are single-conductor; all the other cables are three conductor, each separately insulated, laid up under one insulating jacket and covered with lead sheathing $\frac{1}{8}$ in. in thickness and containing 3 per cent tin. The thickness of the insulation varies slightly with the different manufacturers, the specification calling simply for time-tests of double normal voltage. The curves shown represent present-day average prices for the different cables indicated. The curves were obtained by plotting the prices quoted for the several characters of insulation at the voltages named and drawing lines, to represent the average, through the points as plotted. The speaker assumes it is fair to conclude that curves obtained in this way correctly indicate the cost of cables at any voltage throughout their length. The price indicated for three 50,000-volt paper insulated single-conductor cables is the average price; that for graded similar cables is the quotation of a single maker; the same with regard to the 75,000-volt cable, except that the cross-section is of 50 square mm. instead of No. 0000.



Where No. 0000 conductors are intended for 50,000-volt service or above, the thickness of the insulation becomes so great with three-conductor cable that it is impossible to put the completed cable through the leading machines at present available. It may be possible to develop machines of larger cross-section, but I believe at present about 3 in. is the largest cable that can be lead sheathed. This means that for the higher voltages requiring thicker insulation, single-conductor cables must be used which means increased cost compared with three-conductor cables. This is to the disadvantage of the higher voltages, but is compensated for by the fact that fewer spare cables are required as a reserve.

The conclusion that the speaker comes to from a consideration of these curves is that 25,000 volts is not the commercial limit for underground cables. There is no reason why the same commercial advantages cannot be obtained by increasing the potential to 35,000 or 40,000 volts, where the type of cables are three-conductor, because the cost increases in the same ratio as the potential both above and below 25,000 volts. Similarly, for certain conditions it will be commercially advantageous to use 50,000 or even 75,000-volt cables.

John W. Lieb, Jr.: I would like to say a word or two on the contribution made by Mr. Merz. As several of the speakers have said, the local conditions in this country are so different from those that prevail abroad, that it is very difficult, without giving them most careful consideration, to determine which is the better type of construction to use.

My own experience with underground construction abroad dates from 1882. In that year quite an extensive underground system was laid in Milan, Italy, using Edison tubes. It took just about six months in that particular locality to destroy a wrought-iron tube laid underground. The accumulated detritus of many centuries, together with the poor drainage and sewerage system, made these tubes subject to corrosion to such an extent that it showed conclusively that the Edison tube system which was in successful practical use in this country was not adapted to the new conditions, and as a result after 1885, steel-banded, lead-covered cables were used exclusively.

A few years later there was laid in that city one of the first 2,000-volt alternating current underground systems, using concentric cables. This type of cable, lead covered with steel band armor, has given splendid results abroad and is the type most extensively used.

The type of cable advocated by Mr. Merz is very much better suited to European conditions than our American drawing-in system, as they have to deal largely with built-up communities where they can more easily and readily foresee the probable future requirements.

Philip Torchio: Seven years ago Dr. Steinmetz gave us the mathematical theory of surges on high-tension systems. Since then the oscillograph applied to high-tension cable systems has confirmed graphically the values deduced from formulas and the numerical values of line and power constants, making the results of these investigations of great benefit to the operating and designing engineer alike. It is interesting to compare these oscillograph records with similar data obtained a few years ago by David on a considerably smaller system in the south of France and by Patchell in London. Messrs. Junkersfeld and Schweitzer have also experimented on a 20,000-volt line, which is double the voltage previously experimented upon. Their conclusion, that 20,000-volt cables do not act differently from lines at lower voltages, is not only valuable for its industrial application but also for the practical confirmation of the theories that have been advanced and their applicability to wider limits. For this the Institute is greatly indebted to the authors.

As a contribution to the experimental data of this paper the writer wishes to present a record of disturbances in the high-tension cable system of The New York Edison Company during the last few months. The history of all cable disturbances of this company for the first five and nine years was presented to the Institute by the writer in June 1903 and October 1907 respectively.

These two communications described the two types of instruments to give immediate indication of every " high-tension ground " on the cables or system. The first is an electrostatic ground indicator with suitable contacts and alarm bells, and gives indications of low resistance grounds only. The other is a selective ground indicator and indicates the lowering of insulation in advance of a dead ground, and also designates on which particular feeder (averaging 80 or 90) the ground is developing or has developed. Reference in the table is made to each type of instrument respectively by the designation, "electrostatic ground detector," and, "selective ground indicator."

From the theoretical point of view the above records are interesting in showing the existence of the time-element in the breakdown of insulation, the effects of momentary grounds on the system, etc.

This record, as well as the previous ones reported, includes abnormalities of all kinds however unimportant or inconsequential they may have been from an operative standpoint or in their effects on the system as a whole. A large proportion of the so-called " disturbances " or " defects " referred to were not on the Edison system at all but were located on the premises of large customers, to whom high-tension current was supplied.

As illustrating the value of these selective ground indicators from an operating standpoint, it may be of interest to cite one case of cable breakdown which occurred in January 1907, before the selective ground indicators were installed. One phase of a cable grounded and some sixty odd feeders had to be taken out of service, one at a time, before the grounded cable was

TABLE I

Records of the operation of the electrostatic ground detector and selective ground indicator from June 1 to October 6, 1908

Date, 1908	Cause of indications	Location of defect	Time elapsed after location of defect by selective indicator before electrostatic ground detector operated	No. of drops down on selective ground indicator at first shock*	Remarks
June 10	Short-circuit made by construction dept.	In sub-station	0	1	Cleared by automatic opening of feeder switches.
" 24	Burn-out of motor coil	" "	0	1	Cleared by sub-station operator.
" 25	Switch accidentally grounded	" "	0	1	Cleared by sub-station operator.
" 26	Ground and short-circuit on 2 high tension feeders	In subway	0	2	Simultaneous ground on opposite phases of 2 high tension feeders caused short circuit which was cleared by the automatic opening of feeder switches about 2 sec. after its indication.
" 26	Short circuit on high tension feeder	In sub-station	Electrostatic did not operate.	1	Feeder switch opened at same instant ground was indicated.
Aug. 1	Ground on cable	" "	0	1	Cleared by sub-station operator.
19	Ground on one phase of high tension feeder	In subway	10 to 15 sec.	2	Feeder taken out of service by system operator.
" 28	Burn-out of 75 kw. lighting transformers	In sub-station	0	4	Cleared by sub-station operator.
Sept. 2	75 kw. lighting transformers grounded	" "	7 hr. 40 min.	2	Instantaneous grounds occurring at 2 a.m., 7 a.m., 3:30 a.m., 4:30 a.m., 5:50 a.m., 9:36 a.m., 10:12 a.m., 10:39 a.m. Finally cleared by cutting out lighting transformer.
" 19	Burn-out of 400 kw. transformer	" "	10 sec.	1	Cleared by automatic opening of feeder switches.
Oct. 2	Ground on one phase of high tension feeder	In subway	3 to 4 sec.	5	Feeder taken out of service by system operator.
" 4	Ground on lighting transformer	In sub-station	0	2	Instantaneous grounds occurring at 2:45 p.m., 5:05 p.m., and 9 p.m. Finally cleared by cutting out lighting transformer.

In all the above cases both the electrostatic ground detector and the selective ground indicator operated.

* In all cases where more than one drop fell at the first shock the drop on all clear feeders stayed in after being once restored

located. Two hours elapsed from the time the ground occurred before the faulty cable was located.

Attention is called to the fact that in five out of twelve of the cases reported the selective ground indicator gave its indications long enough in advance to enable the operator to clear the defect before actual short-circuit occurred.

The practice of the New York Edison Company in subjecting cables to high-potential tests differs somewhat from that given in the paper, in that new, altered, or repaired cable is subjected to a test of double working voltage between conductors and ground for 2 minutes, and 20 per cent above working voltage between conductors for 3 minutes.

Chas. P. Steinmetz: Electrical engineers are indebted to the authors for demonstrating that underground cable systems of magnitude and power can be operated with very few cable breakdowns, and, further, in such a way that the cable breakdowns do not involve the interruption of the system, but can be taken care of perfectly by the protective devices. This is the more reassuring when we realize that the destructive possibilities vary in almost direct proportion with the power back of the system. Underground cables have been operated for many years on arc circuits on 5000 or 10,000 volts with very little trouble. But these systems were of limited power. A cable of the same size operating under the same voltage may give satisfactory results on one system; on another results may be unsatisfactory, due to the greater power back of it.

It would be interesting to investigate still further how much stored energy there is available in this system, not merely the rated capacity of the engines and generators, but the energy stored in the magnetic field of the conductors, in the electrostatic field, and in the mechanical momentum of the synchronous apparatus, generators as well as synchronous motors and converters. All this apparatus is ready without a moment's notice to feed back their energy into any part of the system. It would be interesting, too, to calculate the maximum discharge rate of this stored energy, because it would be found that this apparently enormous power of 118,000 kw. is insignificant compared with the maximum possible discharge rate, which probably runs into the millions of kilowatts. This must be taken into consideration in discussing the action and operation of a cable system.

Theoretical investigation as usually found in the literature of this subject, shows that the maximum possible voltage cannot exceed double voltage. Here the spark-gap records much more. This shows that much of our so-called information on transient phenomena does not agree with the actual facts; that our knowledge is still incomplete. I believe that this subject is just passing from a chaotic state into a state where we shall begin to know something of value. Ten or fifteen years ago our theoretical ideas of the operation of transformers and generators did not agree with the performance of these apparatus. The same condition exists now with these transient phenomena. The phantom circuit of distributed capacity and inductance with which most of the literature deals, is a uniform circuit of uniformly distributed capacity and inductance, which oscillates with a definite frequency. Is it very different from the circuit existing in practice, which is a combination of circuits of different constants joined to the massed inductance of generators, transformers, etc., and in these complex circuits the voltage rise may greatly exceed double value.

I think that this investigation could be extended still further by inserting spark-gaps across sections of the circuit, across inductive devices inserted in series in the circuit, as current transformers. A short spark-gap, with a tell-tale paper, connected across the current transformer at the terminal stations and middle stations of the high-voltage system would give an indication of the direction in which the disturbance passed, and how far it extended. Furthermore it would be important if one could get an indication not only of the voltage, but also of the frequency of these disturbances, and of the volume of the high frequency oscillation of these transient phenomena. I believe that this can be done by combining a condenser with the spark-gap. If across the circuit a Leyden jar is connected in series with an air inductance, and the spark-gap is shunted across the inductance, such a system takes a current and produces a voltage across the spark-gap depending on the frequency and voltage. As the plain spark-gap gives us the voltage, the combination of the condenser gap and ordinary gap would give an indication of the frequency; and as the volume of the discharge through such a condenser circuit depends on frequency and voltage, a fuse in series with the condenser circuit would give an indication of the volume of the high frequency oscillation.

I do not think that the burning off of the needle points in the ordinary spark-gap is a satisfactory indication of the volume of the oscillation, because the current following the discharge is also the normal machine current. The result depends to a considerable extent on the point of the generator wave, but a spark-gap and a condenser in series would exclude the machine current. The practical importance of the investigation of frequency is that perhaps the destructive effect of such a high voltage depends very largely on the frequency. In such a cable system the high voltages may be fairly moderate in their frequency, perhaps not more than a few thousand cycles at the highest, or they may be of extremely high frequency, many hundred thousands of cycles. In the latter case they would be local, and even at considerably more than double voltage they would be practically harmless; with low frequency they may extend over a very considerable part of the system and be most destructive.

The greatest assistance in studying what may occur in the circuit is afforded by the oscillograph. This instrument bears the same relation to the electric circuit that the indicator does to steam engine practice. The oscillograph should enable the electrical engineer to determine all that takes place in the electric circuit; he should be able by means of it to recognize a danger signal, and know when the disturbance is harmless. That is, he must become familiar with the meaning of the different wave shapes.

In the oscillograms of the current there are quite a number of shapes. For instance, in Fig. 7 there is the characteristic effect of the hysteresis cycle of the transformer. In Fig. 5 there is shown the effect of the line intensifying higher harmonics. In this particular case it is the fifth harmonic. It is gratifying to see in all these oscillograms that there is nothing to indicate any dangerous condition in the circuit except the voltages at 7 and 8 in the two curves in Fig. 6. They look suspicious, and should be further investigated.

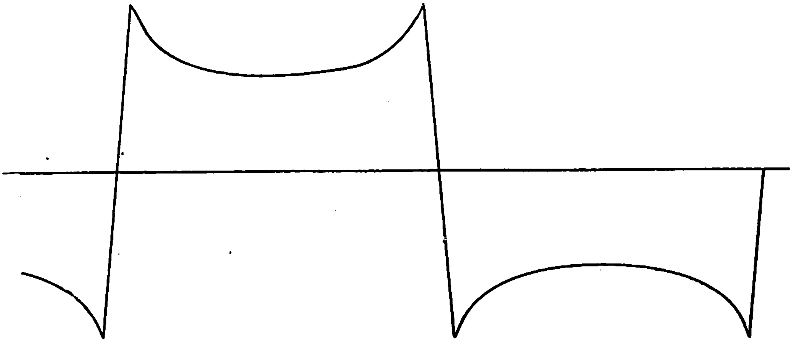


FIG. 1—Theoretical Arc Characteristics

One of the most destructive things in a cable system is an arc, and it is important for the engineer who is using the oscillograph to be able to notice the first sign of an arc characteristic. This characteristic is in most cases very definite, it is a double peak of voltage, a characteristic double peak. Occasionally there are double peaks in generator waves, especially in three-phase machines between the neutral and the line. In that case there is no danger, but when a curve like that in Fig. 1 is shown, then there is something in the system in the form of an arc, which is likely to produce destructive voltages. The characteristic is a rapid rise and rapid dropping off, to two sharp peaks separated by a wide valley. The first peak frequently is far higher and the second one may almost disappear, as in Fig. 2. Even the magnitude of the danger of producing destructive voltages by the arc can be recognized from the curve, by the pointedness of the peaks, and occasionally in the extreme case one sees the first peak resolved into a local oscillation, and the valley then more flattened out, as in Fig. 3.

I hope that the authors will extend the scope of their investigation and give the frequency and the volume of the discharges. I think that at some future time the oscillograph will be a general adjunct in all systems. The oscillograph will be at hand so that it can be immediately utilized when anything goes wrong—a generator runs away, a machine burns up, or a short-circuit occurs. If these records could be taken at the time they would be extremely important in helping us to avoid these disturbances.

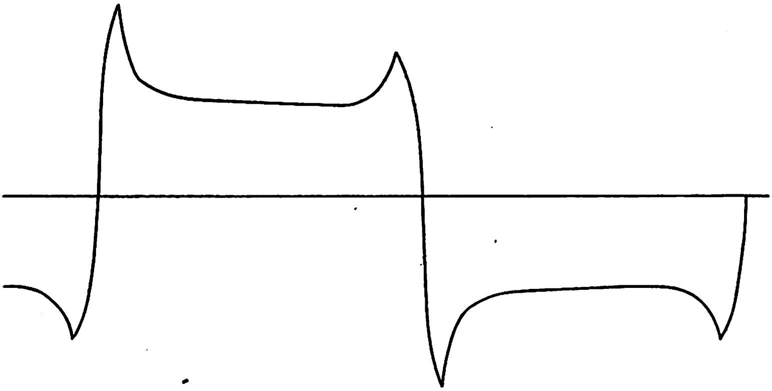


FIG. 2—Arc Characteristics derived from Oscillograms

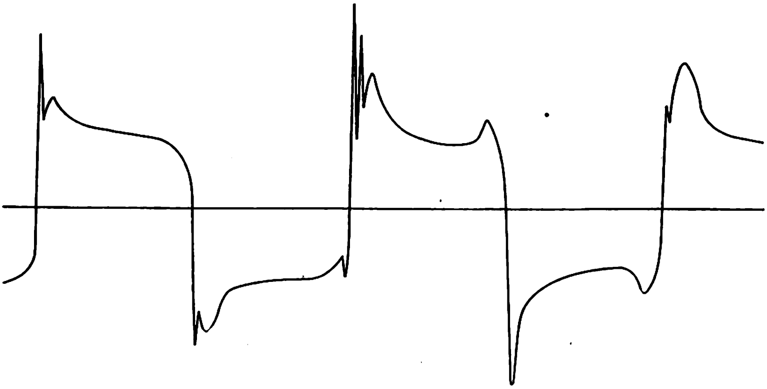


FIG. 3—Arc Characteristics derived from Oscillograms

E. O. Schweitzer: In answer to Mr. Fisher's query regarding the meaning of "double-working voltage:" this means double the normal voltage between phases, and between phases and ground; that is, if the normal operating voltage is 19,100 volts between phases and 11,000 volts between phases and ground, the test voltage is 38,200 volts between phases and 22,000 volts between phases and ground.

With reference to Mr. Fisher's suggestion that two and a half times the normal operating voltage be used in making potential tests on new lines on account of the fact that our spark-gaps showed potentials of 25,000 volts for a line operating normally at 19,100 volts between phases and 11,000 volts between phases and ground. We do not consider this advisable, as this double voltage test is applied for a period of one minute, whereas the surge potential lasts for but a small fraction of a second. The strain on the insulation being a function of both the voltage and time, we, therefore, consider this double voltage test sufficient for the purpose.

With reference to our statement of 11,000 volts, mentioned several times at the bottom of Fig. 4. This statement is correct, as it is the star potential of the line that operates at a delta potential of 19,100 volts, which latter voltage is referred to as coming under the class of 20,000-volt lines.

Regarding the footnote stating that when the generators at Fisk Street were grounded through a 2.6 ohms resistance, a voltage rise of 30 per cent more was obtained, than when there was one machine on the system grounded without appreciable resistance. This may be explained by the fact that the voltage to ground of each phase becomes unsymmetrical, due to the drop in potential with large currents through the resistance. The neutral of the generator including the resistance is, therefore, displaced from the true neutral position.

Peter Junkersfeld: I have seen Mr. Merz's "solid" system and the conditions under which it operates, and I believe that under those conditions many of us would do what he has done. For the large cities, however, Mr. Merz himself admits that the drawing-in system is often a necessity. Under most conditions in this country, however, I must disagree with Mr. Merz.

As to Mr. Fisher's comment, I will answer that the insulation of the 20,000-volt 00 cable is $\frac{9}{32}$ in. wall over each conductor, and $\frac{6}{32}$ in. wall over the three and is of paper. The cable is installed mainly in 3.5 in. duct, with square holes, although some two or three miles is installed in a duct that has 3-in. circular openings. The cable is a trifle large for a 3-in. duct, and is intended for a 3.5 in. square duct.

I agree with Mr. Fisher that workmanship is very essential on the joints, but there must be not only good workmanship, but also good compound, and good methods to insure good results.

Our experience with paraffin has not been satisfactory. In making joints it is, of course, absolutely necessary to exclude air, and as is stated in the paper, the joints are filled with a high-grade compound, and this compound, very hot, is poured slowly so that the probability of any air or voids is reduced to a minimum.

Mr. Stott and others have mentioned the increasing danger when the generating capacity becomes so great. In our system the rated capacity of the three stations connected to the system is 100,000 kw. for the Fisk Street station at this time, 28,000 kw. for the Quarry Street station, and 18,000 kw. for the Harrison Street station, making a total of 146,000 kw. We operate the system in two sections, but even with this precaution the possible amount of power that can be delivered instantaneously from either of the two sections is very large indeed because of the instantaneous short-circuit current of the turbine-driven alternators.

Mr. Clark made some reference to the breaking down of the cable to ground. That has been our experience for several years. If the cable must break down at all, we would rather have it break down to ground first. The neutral is grounded, and we use three single-pole relays. The usual experience is, if one of the conductors goes to ground, that at least one of the other two conductors remains continuous and a test can then be made quickly and the fault located in a short time.

Regarding the comparison between the insulation of the 9000 and the 20,000-volt cables. That is largely a matter of local conditions. The 20,000-volt cable has not as large a factor of safety but it does not need it. The 9000-volt cable does, as it supplies a district in the central part of the city.

Regarding Mr. Floy's statement of higher voltage cables, I do not want to dispute the figures he has given, but cables for 35,000 or 50,000 volts will require special duct or other construction. I think that it will probably be some time yet before we see any very extensive 35,000 or 50,000-volt underground systems. It is difficult to justify them commercially, even if they could be installed and possibly operated with reasonable success.

Ralph D. Mershon (by letter): The authors suggest that, as transmission voltages increase there may be instances where it will be advantageous to build transmission lines after the manner of protected bus-bar construction. This suggestion is rather an interesting one. It is especially interesting to me, because about two years ago I made some estimates on the cost of building a transmission somewhat along the lines I understand the paper to suggest. It occurred to me that if we should build a transmission line with comparatively short spans and with supporting structures just high enough so that there would be no chance of an arc between the lowest point of the line cable and ground, and then build along and over the whole line a casing or continuous house of wire netting, the cost might not be prohibitive, and a number of advantages would result, amongst them being immunity from lightning troubles and ease of repair. An estimate was made with reference to a rough design I prepared in which the line cables were to be about 6 ft. from the ground at their lowest point; the height of supporting structure and length of span being such as would, for this clearance, result in the greatest economy. The idea of the wire netting resolved itself into a high fence of this material, on each side of the line, and for the wire netting roof were substituted a number of grounded cables, supported upon the line structures parallel to the line wires and over them. These grounded cables were to serve the double purpose of protection against lightning and protection against baling wire and similar troubles. The cost of this design was compared with that of a tower line of the same capacity and, while the former was somewhat the greater, the difference in cost was not such as would be prohibitive where large amounts of power are to be transmitted.

If such a construction were used, it would be necessary at road crossings, either to go overhead on high structures or underneath through tunnels. The former could be carried out without great difficulty, maintaining practically the same construction on the higher supports as that used near the ground; or the latter could be adopted where the contour of the ground rendered it possible to take care of the matter of drainage.

I should not be surprised if, in time, some such construction as that suggested were resorted to for transmission lines carrying very high voltages, especially as it seems to me not unlikely that as voltages go higher the insulator will develop to a form and a size comparable with that of a transmission line pole. With the construction suggested, then, the three-line conductors will be best carried upon three separate lines of poles, each pole being, for the major portion of its length, an insulator.

Of course, instead of the grounded cables and the wire fences, we might substitute sides and a roof of corrugated iron which would not only afford the protection previously mentioned, but also protection against the weather, rendering the insulation problem less expensive. In such case, however, the damage resulting from an arc to ground or between the line cables would probably be more serious than in the construction above proposed.

H. W. Peck (by letter): About one and a half years ago suspicion was aroused that there were high-tension surges on a 13,200-volt underground transmission system in Baltimore, and oscillograms were taken under various conditions to determine the actual presence and causes of the surges. The system, at that time, comprised four 2000-kw., 13,200-volt star-wound generators commonly run with the neutral of one machine grounded through an iron-grid resistance; about 24 miles of 0000 three-conductor, paper insulated, lead-covered cables; four 13,000-volt, synchronous motors driving 60-cycle generators, and a number of step-down transformers, supplying synchronous converters. The oscillograms were taken at one sub-station located about 4 miles from the generating station. No rise of potential was discovered at the time of synchronizing an additional generator at the power house or a 1000-kw. synchronous motor at the sub-station, nor at the time of taking off either of these machines. The only condition observed which did give a rise in potential was the connecting of the dead line to the system or to a single generator with which we were testing. With the neutral of the test generator not grounded we obtained a rise in potential of 180 per cent of the normal. With the neutral of the generator grounded through heavy copper wire we obtained rises of potential of 150 per cent, 300 per cent, and 400 per cent of normal.

Further investigations were made with the oscillograph of the overhead distribution and in so doing one observation resulted which is perhaps of value in connection with such investigations. While adjusting for a certain test and observing the form of curve by looking at the image on the ground glass and shaking the head at right angles to the motion of the light there was observed a very irregular wave form. Investigation disclosed no apparent cause for this irregularity and repeated attempts were made to duplicate the same with the film, resulting finally in getting something very similar to that which had been observed. This suggested the value of throwing a reflection of the oscillogram by means of a vibrating mirror upon a screen and observing the reflection for a long period of time, noting whether irregularities did exist and if so endeavoring to ascertain any peculiar conditions obtaining at that time.

BY-LAWS

OF THE

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

[*Adopted by the Board of Directors, April* 22, 1904, *Amended February* 24, 1905, *March* 24, 1905, *February* 23, 1906, *May* 19, 1908, *and November* 13, 1908.]

The Constitution as amended May 21, 1907, authorizes the adoption of By-laws as follows:

ART. VII, SEC. 40. *The Board of Directors shall prepare and adopt a series of By-laws which shall govern its procedure and that of the committees, under this Constitution. Such By-laws shall be adopted or may be amended by a concurring vote of not less than twelve* (12) *members of the Board of Directors; provided, that the text of a proposed By-law or amendment shall be furnished to each member of the Board of Directors at least ten days before the meeting at which a vote on the same will be taken.*

BY-LAWS.

MEMBERSHIP.

SEC. 1. Members, Associates, and Honorary Members, are authorized to use the following abbreviations indicating their grade of membership in the INSTITUTE.

Honorary,	Hon. Mem. A. I. E. E.
Member,	Mem. A. I. E. E.
Associate,	Assoc. A. I. E. E.

The term member (when printed without a capital), where used herein, includes Members, Associates, and Honorary Members.

It shall be the duty of all members to call the attention of the Secretary to the improper use of INSTITUTE badges or symbols, or to claims made by non-members that they belong to the INSTITUTE. The Secretary shall thereupon investigate the facts and lay the matter before the Board of Directors.

SEC. 2. An applicant for admission as an Associate who is not personally known to three members of the INSTITUTE, may refer for one or more of his three references preferably to a member or members of any grade in the societies designated in Section 3, or to any citizens of standing in the community; and the members of the Board of Examiners may then, if satisfied of his merits, endorse his application in the usual manner.

SEC. 3. An applicant for transfer who certifies that he is not personally known to five Members may refer for one or more of his five references to an Associate or Associates of the A.I.E.E., or to one or more professional engineers of recognized standing who may belong to any of the following named societies: American Society of Civil Engineers; American Society of Mechanical Engineers; American Institute of Mining Engineers; The Canadian Society of Civil Engineers; The Society of Naval Architects and Marine Engineers, all of America; or, the Institution of Civil Engineers, the Institution of Mechanical Engineers, or the Institution of Electrical Engineers, of Great Britain; or of any approved American or foreign national engineering body.

SEC. 4. The names of applicants for transfer to the grade of Member, after being recommended for transfer by the Board of Examiners, shall be posted in the PROCEEDINGS, and final action thereon shall not be taken by the Board of Directors until one month after such posting, in the case of all applicants residing in North America, and until three months after such posting, in the case of all other applicants.

SEC. 5. Objection to the admission of any candidate for the grade of Associate, or for transfer to the grade of Member, must be accompanied by reasons for such objection, all statements to be treated as confidential.

SEC. 6. The privileges attaching to membership in the INSTITUTE, shall not be accorded to applicants for admission until they have been duly elected, and have paid their entrance fees and current dues.

SEC. 7. A prompt notification of his election as an Associate, accompanied by a statement of his initiation fee and dues, shall be mailed to each candidate by the Secretary. A second notice of his indebtedness shall be sent by registered mail 30 days (60 days in the case of members residing outside of North America) later to every candidate remaining in arrears. The Secretary may, at his discretion, cancel the election of any applicant remaining in arrears 30 days (60 days in the case of members residing outside of North America) after the mailing of the second notice.

SEC. 8. A member who has resigned in good standing, may, on the approval of the Board of Directors, be reinstated without payment of entrance fee, and shall be entitled to admission to the grade last held by him, after review of his professional record by the Board of Examiners. If the applicant so elects, he may retain his original date of election or transfer, by payment of all dues which would have accrued during the interim, and he will then be entitled to such INSTITUTE publications issued during such period, as are available.

SEC. 9. Any resignations received by the Secretary not later than June 1st of any year (September 1st in the case of members residing outside of North America), may, at his discretion, be considered as having been received as of May 1st preceding.

SEC. 10. The rights and privileges of each Honorary Member, Member, or Associate, shall be personal to himself, and shall not be transferable or transmissible by his own act or by operation of law.

SEC. 11. An Honorary Member, Member, or Associate, whose membership shall terminate for any cause shall have no right or interest in any property of the INSTITUTE or any claim or privilege in or against the INSTITUTE or pertaining thereto.

PAYMENT OF DUES.

SEC. 12. Annual dues are payable in advance upon receipt of bills dated May 1st, the beginning of each fiscal year.

SEC. 13. A bill for annual dues shall be mailed to each member on or about May 1st. On October 1st a second notice shall be sent to those in arrears. On March 1st following a third notice shall be sent by registered mail to those remaining in arrears, a copy of this section of the By-laws to accompany such notice. Any member remaining in arrears May 1st shall be placed on the Suspended List, shall receive no further INSTITUTE publications, and shall be debarred from enjoying its other privileges until reinstated. At its May meeting the Secretary shall submit to the Board of Directors a list of the delinquents, for its action thereon.

SEC. 14. The mailing of such bills or statements to the last address upon the office Mailing List, shall be considered a valid notice of indebtedness.

BOARD OF DIRECTORS.

SEC. 15. The regular monthly meeting of the Board of Directors shall be held on the same day as the regular monthly meeting of the INSTITUTE. The meeting may also be held in any month when no regular INSTITUTE meeting occurs, the date of such meeting and the hour of all meetings to be set by the President.

ELECTIONS.

SEC. 16. A Manager elected to fill a vacancy for an unexpired term shall be selected from those whose names appeared on the General Proposal List prepared for the last annual election.

SEC. 17. In preparing the Directors' Ticket, candidates shall be voted for by written or printed ballot. The names of candidates for Vice-president should be selected, as far as practicable, from different sections of the country.

SEC. 18. For the guidance of members in the selection of nominees for the annual election, there shall be published in the January and February PROCEEDINGS, each year, a summary of the nomination votes of the preceding year, containing the names of all persons having received at least three per cent. of the entire number of nomination votes cast, and also the names of all directors not included in this list and of ex-Vice-presidents and Managers who have held office at any time during the preceding five years.

SEC. 19. Nomination forms, as provided in the Constitution, shall be sent, upon application, to Associates who have qualified between the dates of February 1st and March 1st; and single copies only, of such nomination forms, shall be sent, upon request, as duplicates, to members who may have mislaid or destroyed their original copies. Nominations may, however, be written on blank paper if the regular form is not available.

OFFICE ORGANIZATION.

SEC. 20. The office organization shall include an Assistant Secretary and an Editor.

The Assistant Secretary shall assist the Secretary, and, in his absence, may act for him, and shall have such other duties as may be specifically assigned to him by the Board of Directors from time to time.

The Editor shall report directly to the Secretary, and shall, under the direction of the Meetings and Papers and the Editing Committees, have charge of the publication of the PROCEEDINGS and of the TRANSACTIONS.

JOHN FRITZ MEDAL.

SEC. 21. The representatives of the INSTITUTE on the Board of Award of the John Fritz Medal, shall be the President of the INSTITUTE, and his three immediate predecessors in office. Each year the president-elect, after assuming the active duties of his office, shall, on the third Friday in January, become a representative of the INSTITUTE on the Board of Award of the John Fritz Medal, and the functions of the senior past-president, in connection with this award, shall then cease and determine. In the event of the death or permanent disability of any of the representatives of the INSTITUTE on the Board of Award of the John Fritz Medal, the Board of Directors shall be empowered to select his successor from among the surviving past-presidents of the INSTITUTE, and such successor shall hold office for the term of the representative in whose place he is appointed.

ADDITIONAL DUTIES OF COMMITTEES.

SEC. 22. Each standing committee shall have a regular monthly day of meeting, as far as practicable. All resolutions or reports which each committee shall forward to the Board of Directors for action, must be signed by the chairman.

SEC. 23. In addition to the duties prescribed by the Constitution, it shall be the duty of the Finance Committee to cause to be prepared for the information of the Board of Directors, a balance sheet each year, to September 30th, showing the financial condition of the INSTITUTE, including the state of each fund which may be separately invested. Also to submit to the Board of Directors at its October meeting a budget of estimated receipts and expenditures for the ensuing year beginning October 1st. It shall also be the duty of the Finance Committee to have the bank books and securities of the INSTITUTE examined, prior to the annual financial statement made in the month of May, and to certify to their correctness.

SEC. 24. It shall be the duty of the Library Committee to advise in regard to the purchase of books or the acceptance of donations for library purposes, on behalf of the INSTITUTE; to prepare an annual report for the year ending April 30th, showing the state of the library, and giving the names of all donors to the library for the preceding year, which report, when accepted by the Board of Directors, shall be printed, and form part of the monthly PROCEEDINGS.

SEC. 25. The Meetings and Papers Committee shall accept no paper from a non-member unless directly authorized to do so by the Board of Directors.

SEC. 26. In addition to the duties prescribed by the Constitution, it shall be the duty of the Editing Committee to exercise a general supervision over all publications of the INSTITUTE. It shall also call the attention of the Meetings and Papers Committee to papers which it may deem unsuitable for publication in the PROCEEDINGS or TRANSACTIONS, assigning specific reasons therefor.

SEC. 27. Each temporary committee appointed to arrange for the holding of the Annual Convention, or for any other purpose involving expense to the INSTITUTE, shall prepare an estimate of its probable expenditure and submit it to the Board of Directors for approval.

SEC. 28. The functions and duties of temporary committees shall be defined by the Board of Directors. At the beginning of each administrative year the Secretary shall transmit to all the members of each temporary committee whose duties may be continued, copies of the original resolutions constituting such temporary committee. It shall be the duty of the Secretary to call the attention of the Board of Directors to work done by any temporary committee outside the scope of the resolution or resolutions which constituted it.

SEC. 29. The expenditures of the INSTITUTE shall be regulated by annual appropriations which shall begin on the first day of October of each year. Each committee shall submit to the Secretary for the information of the Finance Committee in preparing its annual October budget, an estimate of its requirements for the ensuing year.

SEC. 30. No standing or temporary committee shall, under any circumstances, exceed its authorized appropriation without first obtaining the sanction of the Board of Directors.

SEC. 31. For the information and guidance of these committees the Secretary shall each month send to the chairman of every committee which has incurred expense during the preceding month, the following information:

1. Total amount of all appropriations authorized for the current year by the Board of Directors for such committee.

2. Amount in dollars and per cent. of appropriation expended during the preceding month.

3. Amount in dollars and per cent. of appropriation expended during the current fiscal year, including the preceding month.

4. The same information for the corresponding periods of the preceding year, when available.

SEC. 32. The President may invite any non-member to discuss any paper presented at a meeting of the INSTITUTE, and the chairman of any Section may invite any non-member to discuss any paper presented at the Section of which he is chairman.

PUBLICATIONS.

SEC. 33. The regular publications of the INSTITUTE shall include PROCEEDINGS, to be published monthly, and TRANSACTIONS, to be published quarterly, semi-annually, or annually.

SEC. 34. The PROCEEDINGS may have two principal divisions:

1. For current matter and INSTITUTE news;
2. For technical papers, discussions and other matter of an engineering character.

SEC. 35. The TRANSACTIONS shall contain such papers, discussions and other engineering matter previously printed in the PROCEEDINGS, as may be approved for publication in the TRANSACTIONS by the Meetings and Papers Committee and the Editing Committee.

SEC. 36. From the annual dues paid by each member, five dollars ($5.00) shall be deducted and applied as a subscription to the PROCEEDINGS for the year covered by such payment.

SEC. 37. The payment of the annual dues by any member shall entitle him to receive a bound copy of each volume of the TRANSACTIONS for the period covered by such payment.

SEC. 38. The paper or papers presented at the meeting in any month shall be published in the PROCEEDINGS, preferably in advance of the meeting.

SEC. 39. A paper, after being edited and revised for publication under the direction of the Meetings and Papers Committee, shall be returned to the author to obtain his consent to its publication as revised. In case the author shall not consent to publication in the form suggested by the said committee, and a revision acceptable to both the committee and the author cannot be arranged, the paper shall not be presented or published.

SEC. 40. A discussion or communication, after being edited and revised for publication under the direction of the Editing Committee, shall be returned to the author to obtain his consent to its publication as revised. In case the author shall not consent to publication in the form suggested by the said committee, and a revision acceptable to both the committee and the author cannot be arranged, the discussion or communication shall not be published.

SEC. 41. No paper, or written contribution to a discussion shall be given to the press for publication, in advance of its presentation, except by authority of the Board of Directors.

Sec. 42. No person shall receive monetary compensation from the reprinting of any paper or discussion presented before the Institute or before any Section or Branch without previous authorization from the Editing Committee.

Sec. 43. The Secretary is authorized to receive annual subscriptions for the monthly Proceedings, ending with the calender year, at the rate of $10.00 per annum for all countries to which the bulk rate of postage applies. To all other countries the price shall be $12.00 per annum, fifty per cent discount to libraries.

Sec. 44. Existing bound volumes, or bound volumes hereafter published, may be sold to non-members at the following prices:

Paper covers, Vols. I to IV, each	$2.00
Paper covers, later volumes, per year	10.00
Cloth “ “ “ “ “	11.50
Half Morocco “ “ “ “	13.00

A discount of 10 per cent. from the above prices, either for volumes, subscriptions, or parts, may be allowed to publishers and dealers. Members and Associates shall be allowed a discount of 50 per cent. on parts or duplicate volumes to replace those lost or destroyed. They may purchase volumes issued prior to their election, when available, at $5.00 each, either in paper or cloth covers, or at $1.00 extra for half morocco binding.

Sec. 45. An Associate shall be entitled to receive the bound volume or volumes of the Transactions, beginning with the volume including the corresponding half year in which he has paid his entrance fee, and such single copies of the Proceedings for the same period as he may apply for, and which are available.

Sec. 46. A member who has presented a paper to the Institute, which has been printed in the Proceedings, shall be entitled, upon application, to 15 copies of the paper, or, at the Secretary's discretion, of the Proceedings containing such paper, and to the same number of copies of the discussion, provided such copies are available.

Sec. 47. A catalogue of members shall be published annually. A directory, in which the names are grouped geographically (Members' names shall be distinguished from those of Associates by a difference in type), may also be issued. The Constitution and By-laws of the Institute shall be printed in at least one of these publications. Either the catalogue or the directory, or both, at the Secretary's discretion, may be issued as a part of the Proceedings.

Sections.

Sec. 48. The principal work of a Section shall be the holding of regular meetings for the presentation and discussion of papers on matters relating to electricity, and to the allied arts and sciences.

Sec. 49. A Section of the Institute may coöperate with other local engineering organizations in the holding of joint meetings, and may invite members of such organizations to its meetings.

Sec. 50. A petition for the formation of a Section shall specify the territory to be included and shall be signed by not less than 25 members residing therein.

Sec. 51. The territory of a Section shall include the locality naturally tributary thereto, but shall not include territory so remote that members cannot readily attend meetings.

Sec. 52. A Section shall be known as: The (name of place) Section of the American Institute of Electrical Engineers.

Sec. 53. In the initial Section organization only petitioners shall have the right to vote.

Sec. 54. In addition to Institute members the Section by-laws may admit other persons interested in engineering, who shall have all the Section privileges except those of voting and holding office.

Sec. 55. The terms of office of the Section Chairman and Secretary shall coincide with that of the President of the Institute. They may or may not be eligible for reëlection as prescribed in the Section by-laws.

Sec. 56. The Board of Directors may at any time rescind the authorization of any Section and terminate its existence.

Sec. 57. Papers and discussions presented before a Section or Branch shall be the property of the Institute, and may be published only on authorization of the Editing Committee.

Sec. 58. The Executive or other suitable Section or Branch committee in charge shall be responsible to the Editing Committee for all Section or Branch papers and discussions. Such matter as is approved by such local Section or Branch committee, as suitable for publication in the Proceedings, shall be presented to the Secretary of the Institute for consideration by the Editing Committee, who in judging its suitability shall be governed by the same reasons as are applied to similar matter offered for presentation at Institute meetings.

Sec. 59. Section or Branch papers and discussions not published in the Proceedings may be published elsewhere, with the statement that they have been presented before such Section or Branch, provided that previous approval of such publication has been secured from the Section or Branch committee in charge, and from the Editing Committee. The Editing and the Section or Branch committees may authorize the publishing of a Section or Branch paper or discussion without reference being made to its presentation before the Section or Branch.

Sec. 60. It shall be the duty of the Secretary of the Section to send to the Chairman of the Sections Committee, on or before October 1st of each year, an estimate of the appropriation required from the Institute for the expenses of the Section during the year ending the 30th of the following September. The Sections Committee shall apportion among the Sections such appropriation as may be authorized by the Board of Directors, and shall notify the Secretary of each Section of the amount apportioned to it. Such amounts may be drawn upon only for the reasonable expenses of the engineering meetings of the Section upon presentation of original bills endorsed by the Section Secretary and for the transportation expenditures of the Section's official delegate to the Annual Convention.

STUDENTS.

SEC. 61. Any person pursuing a regular course of undergraduate study in electrical subjects, in any university or technical school of recognized standing, may be enrolled as a "Student of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS," as hereinafter provided.

SEC. 62. Each application for enrolment as a Student shall be endorsed by a member of the INSTITUTE. It shall be passed upon by the Board of Examiners, and submitted to the Board of Directors for action.

SEC. 63. The annual Student fee shall be three dollars ($3.00), payable in advance. The period of Student enrolment shall not exceed three years, and shall date from the first of January nearest the date of filing application.

SEC. 64. The annual fee of three dollars ($3.00) paid by each Student shall be applied as a subscription to the PROCEEDINGS for the year covered by such payment.

SEC. 65. Students enrolled under the provisions of these By-laws shall each be entitled to receive the regular monthly PROCEEDINGS and ordinary notices of meetings. They will be permitted to purchase the current TRANSACTIONS at $3.50 per year during the period of their enrolment.

SEC. 66. Student privileges may be withdrawn at any time by the Board of Directors.

SEC. 67. A Student changing his mailing address without notifying the Secretary shall be entitled to available duplicate copies of parts of the PROCEEDINGS upon payment of twenty-five cents for each part.

UNIVERSITY BRANCHES.

SEC. 68. Any member who may be connected with a university or technical school of recognized standing, having a course in electrical engineering, may, upon the approval of the Board of Directors, organize Student meetings, to be held under his direction, such Student meetings to be designated as (name of institution) Branch of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

SEC. 69. University Branches shall organize by appointment or election of an Executive Committee of any suitable number of which the said member shall be a member, and of which other members or the enrolled Students of the INSTITUTE may constitute the other members. This organization shall be subject to the approval of the Board of Directors. Other students in the electrical engineering course of the institution may attend the meetings, under conditions to be prescribed by the University Branch.

Sec. 70. The member, by whom the University Branch shall be organized, or the member who succeeds him on its Executive Committee, shall be responsible to the Secretary of the INSTITUTE, for the conduct of its affairs, and shall make regular reports to the Secretary, of the proceedings at its meetings.

Sec. 71. At the meetings held by University Branches the papers read and discussed may be either original papers, or may be papers read before one of the regular meetings of the INSTITUTE. The Secretary of the INSTITUTE may send to University Branches a limited number of advance copies of the papers of the INSTITUTE.

Sec. 72. The INSTITUTE shall publish, from time to time, a list of universities and technical schools in which University Branches have been organized, and brief notices of the proceedings of their meetings.

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A paper to be presented at the 234th meeting of the American Institute of Electrical Engineers, New York, February 19, 1909.

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(*Subject to final revision for the Transactions.*)

PRIME MOVERS

BY CHARLES P. STEINMETZ

I.

Electric energy is not a primary energy; that is, it is not found in nature, nor directly producible to any appreciable extent from the stores of energy available in nature—water power and the energy of fuel. To become available for conversion into electric power, the energy found in nature must first be converted into mechanical rotation by some form of prime mover. The engineering characteristics of these converting apparatus may be classed under two main groups, those referring to economy and reliability, respectively. In both, the electric machine, whether generator or motor, ranges very high: its efficiency is virtually unity; its size, first cost, and maintenance small; its reliability great. In the cost of electric power the electric machine plays only a subordinate part; the essential element in determining the cost and the reliability of electric power is the prime mover; that is, the intermediary step between nature's stores of energy and the dynamo shaft.

The cost of electric power consists of three parts.

A. The fixed cost or permanent cost; that is, the cost depending on the size of the station, but not on the amount of power supplied by it.

B. The proportionate cost; that is, cost proportional to the amount of power delivered.

C. The reliability insurance; that is, the additional cost required to assure the desired reliability or continuity of service.

A. FIXED COST

1. *Interest on the investment in the plant.* This factor varies very greatly with the form of the available energy. It is frequently

very large with water power, due to the hydraulic development required—dams, pipe-lines, land to be flooded for water storage, power stations and prime movers, transmission lines, etc.

It also depends on the prevailing rate of interest; on local conditions—whether a market is waiting for the power and capital for the development easily obtained; whether a market is within reach and can be developed; or whether a market has first to be created.

2. *Depreciation of the plant.* This factor is different for different parts of the plant. For instance it is very low for buildings and for line copper; it is high for apparatus such as railway motors, which by the nature of their service operate on a narrow margin.

In considering depreciation, the " useful life " of the apparatus may often be much shorter than the total life. The ratio of the useful life to the total life varies with different apparatus. Electrical machines and prime movers and other parts of the plant, for instance, may still be in condition to give many years' service, but nevertheless their further use is uneconomical. Their useful life is thus ended. This condition may be due to the advance of the art, which makes other types of apparatus so much more economical that the cost of the difference in economy properly capitalized exceeds the cost of reconstruction of the plant. It may be due to the fact that with the increase of the market the size of units initially chosen may have become too small, or the space-economy too low, or the voltage too low for economy. Furthermore, the cost of attendance or of maintenance may be so much lower with the more modern apparatus as to make it uneconomical to retain the existing plant.

Just as it was realized many years ago that with the incandescent lamp there was a difference between the total life and the useful life, that after a definite period it did not pay to maintain incandescent lamps in service, even if still operative; so with all engineering apparatus a similar " smashing point " exists, a point where economy requires renewal of the plant, even if still operative. At this point the useful life of the old plant is ended; it should be thrown out with whatever salvage is feasible—either by use as reserve plant, or to take care of peak loads, or to be operated elsewhere when space economy limits the useful life. In considering depreciation, the useful life of the apparatus should thus be considered.

3. That part of the operating expense which does not depend on the use of the plant, as superintendence some supervision, etc., such repairs as maintenance of dams and hydraulic development, etc.

B. PROPORTIONATE COST

1. This comprises the cost of energy and accessories to its conversion—fuel, condensing water and lubricating oil in thermodynamic engines, water (where a charge is made for the water power) and oil in hydraulic plants, etc.

2. Labor and attendance, including that part of supervision which varies with the power utilized.

3. Maintenance, repair and depreciation of the plant, as far as they depend on the use of the apparatus; for instance, brush renewals, commutator repairs, railway motor depreciation, etc.

C. RELIABILITY INSURANCE

1. This comprises the overload capacity of apparatus in power, voltage etc., provided to take care of emergencies.

2. Duplication of parts of the plant, as reserve units, duplication of exciter plant, of lines, and feeders, etc.

3. Additional plant, as steam reserve with water-power plants, storage-battery reserve, tie lines with other systems, etc.

Some of the items of the cost may belong partly in one, partly in the other class; depending on local conditions, it may properly be chargeable to either one or another subdivision. For instance, the cost of developing water storage would belong under *A*, if the power capacity of the plant depends on it, while it would be chargeable to reliability insurance *C*, if provided to guard against failure of the power in unusually dry seasons.

The relative weights of *A* and *B* depend largely on the load-factor; that is, the ratio of the average to the maximum power. With a poor load-factor. item *A* is far more important. It recedes in importance with the improvement in the load-factor.

Attention is drawn to the recognition of Class *C*, the reliability insurance, as a distinct and essential part of the cost of power, separate from *A* and *B*. Item *C* again consists in part of the character of fixed cost, and in part of the character of proportionate cost. Nowadays, when the lay public is interested in the cost of electric power, and is comparing plants which may be very different in regard to reliability of service (as supply from a water power over a single transmission line without steam reserve compared with a city steam station with storage-battery reserve), it appears desirable to recognize the insurance of continuity of service as a separate part of the cost of electric power.

The great difficulty met with in discussing reliability of service is the absence of an established standard; for what one engineer may consider as perfectly satisfactory service, may be considered as entirely unsatisfactory by another engineer.

A classification of electric power supply regarding its reliability may be made by the number of shutdowns per year. Four classes of shutdowns may be distinguished, by the time of their duration:

a. Less than one second; that is, less than the time which would throw synchronous apparatus out of step. A few seconds' failure of power in the supply of a synchronous motor or converter means re-starting and synchronizing, and thus for the power users depending on the synchronous machine represents a very much longer shutdown.

b. Less than 20 minutes; that is, the time in which synchronous apparatus in a well organized plant can be put back into service. In lighting circuits, while the failure of the lights is annoying, it is not usually serious, and the loss of time by failure of the power supply is moderate.

c. Less than three hours; that is, the time sufficient to start anew a steam plant, replace or repair damaged apparatus as transformers, repair lines, etc., and a time which, if the shutdown occurs only rarely, in general does not warrant the installation of a separate system of light and power supply, as gas or a private steam plant.

d. More than three hours. This represents a complete breakdown of the system. If this is likely to occur, it requires the provision of private lighting or power plant service whereever power is used from the electric supply system.

In estimating the reliability of service the shutdown of a part of the system would be considered as a part of a shutdown, in proportion to the connected load. Thus a shutdown of a section comprising $1/n$ of the total connected load of the system would count as $1/n$ of a shutdown. This method of counting gives the average number of shutdowns per customer.

Voltage variation beyond the limits permissible in good service—about 2% in lighting, and 10% in power supply—would be considered as a partial shutdown, about in the following manner:

A voltage variation of 2 per cent to 10 per cent as one-tenth of a shutdown in a lighting system, but does not count in a power-supply system.

A voltage variation of 10 per cent to 50 per cent as one-half of a shutdown.

A voltage variation of over 50 per cent counts as a complete shutdown.

It appears reasonable to omit from consideration any shutdown made for purposes of change, repair, etc., provided the users have been notified beforehand.

By the yearly number of shutdowns, an electric power supply would be classified as:

1. First class service:

$a < 4$ per year; $b < 1$ per year; c and d absent.

2. Good service:

$a < 12$ per year; $b < 4$ per year; $c < 1$ per year; d absent.

3. Second class service:

$a < 52$ per year; $b < 12$ per year; $c < 4$ per year; $d < 1$ per year.

4. Third class service:

$b < 52$ per year; $c < 12$ per year; $d < 4$ per year.

5. Unsatisfactory service, suitable only as auxiliary power, etc.

Some such schedule of classes of service appears urgently needed, to give a meaning to statements and discussions on character and reliability of service.

The above proposition is probably the best that can be expected at present, without putting too large a majority of the electric systems into the second and third classes. It must be realized, however, that the standard set by it is far lower than that maintained in most gas or water supply systems; that what is here called good electric service would be entirely unsatisfactory in a gas service. However, this lower standard is permissible, due to the far greater safety of electric power, in which case a temporary interruption of the supply is not liable to such disastrous results as would be the case with gas service.

II.

In discussing the features of prime movers it is necessary to distinguish between those which are inherent in the type of apparatus—as the dependence on meteorological conditions in the hydraulic plant, the high temperature in the gas engine—and those which are incidental. The incidental features are due to the particular form of design, and therefore defects from this cause are usually temporary. While a defect in the prime mover may be just as serious to the operation of the plant, even if not inherent in the type of apparatus, in a comparative discussion such features cannot be given the same weight, as they are not permanent. They are eliminated with the advance of the art, or avoided when recognized; as, for instance, the difficulties found with the convection of superheated steam, due to the considerable expansion and contraction of piping caused by the high temperature differences.

Most of the features of prime movers pertain either to economy or to reliability.

A. Economy

1. *Power economy or efficiency.* With a thermodynamic engine the total efficiency is the product of mechanical efficiency, thermodynamic efficiency, and producer efficiency. The thermodynamic efficiency is the ratio of the available energy in the engine to the total heat energy supplied to it. The mechanical efficiency is the ratio of the mechanical output at the engine shaft to the available energy in the engine. The producer efficiency is the ratio of the total energy of combustion of the fuel to the heat energy supplied to the engine; it thus comprises furnace efficiency, boiler efficiency, superheater efficiency in a steam engine, or producer efficiency in a gas-producer plant, etc.

The thermodynamic efficiency depends essentially on the temperature range utilized by the engine, and to a lesser extent on the thermodynamic cycle used by it. It increases with increase of the temperature range.

The mechanical efficiency depends on the size per kilowatt output of the cylinder volume, on the temperature range, the pressure and the pressure differences, the momentum of the moving parts, their velocity and the nature of the velocity, whether reciprocating or rotating, etc. In general it decreases with increasing size and mass per kilowatt, with increasing speed, (especially when reciprocating) and with increasing temperature and pressure differences. It thereby depends largely on the available energy per unit volume and per unit weight of the working fluid.

Consideration of the producer efficiency opens such a wide field as to be beyond the scope of this paper.

As the cost of the energy is only a part of the proportionate cost of power, the importance of the efficiency varies with the proportion which this part of the cost bears to the total cost.

It thus depends upon numerous considerations—the size of plant, load-factor, etc. In general, high engine efficiency increases in importance with increasing size of plant, and with increasing load-factor, and in such plants becomes the most important factor. In small plants with a poor load-factor it may drop into secondary rank, compared with the fixed cost A, and the cost of maintenance and repair, especially if in the design of the plant the mistake is made of giving too much attention to high efficiency, and thereby too little to reliability and low maintenance.

2. *Space economy.* This factor depends essentially on the engineering skill and judgment in the design of the plant, and on the type of the prime mover. It affects the fixed cost of power, and varies greatly in importance; for instance, space economy in the huge plants of our large cities is of very great importance, while for smaller country plants, or plants in locations where unlimited space is available, it becomes of very little importance.

3. *Investment economy.* This depends largely on the available market, and the desired quality of the power. It affects the choice of the prime mover; for with an assured market, requiring a high grade of service, the large investment of a first-class modern plant with the best type of prime movers and ample reserve is most economical. In many of the earlier railway plants the conditions were such that single-cylinder, non-condensing engines of the cheapest type gave the most economical and occasionally the only feasible arrangement. But even in the large first-class plants, in those parts of the plant that are only occasionally called upon for service; that is, which have a very low load-factor, good judgment may suggest a cheaper and correspondingly less efficient type of apparatus than would be economical in the engines which are continuously in service. Such a reserve and emergency plant thus offers a means of utilizing machinery which in the main plant has finished its useful life. To some extent this applies to the thermodynamic reserve of a water-power plant, especially where it is only rarely called into service, and economy in first cost and in space and simplicity may far outweigh high efficiency.

4. *Labor economy, as determined by the amount and character of attendance required.* With a high price and poor quality of skilled labor, prime movers which require a higher grade of attendance become less economical than less efficient prime

movers which can be operated by unskilled labor, or require only very little of skilled labor, and especially in our country, the reduction of the amount of high-grade skilled labor is economically necessary. It is this feature which has forced the designers of prime movers and electrical apparatus to devote their attention chiefly to make the apparatus as "fool-proof" as possible, even if efficiency and other characteristics have to be sacrificed to some extent. This fact has to a considerable extent determined the trend of development of the industry, so that types of apparatus which have proved entirely satisfactory in other countries were a failure here, until they had been re-designed to meet the requirements of being operated by the available class of labor. A characteristic instance of the effect of price and character of labor is the general introduction of the enclosed arc lamp in this country, while abroad the open arc is universally used. There the enclosed arc has never been accepted, due to its lower efficiency. As a result, the experience gained abroad with different types of prime movers and other apparatus is not directly applicable in our country, and conversely.

5. *Maintenance, repair, and depreciation.* This depends largely upon the type of prime mover, and in thermodynamic engines on the cycle used in the engine. Higher temperature differences, greater cylinder volume and piston pressure, heavier moving (especially reciprocating) masses, higher speeds (especially of reciprocating masses); in short, greater mechanical and temperature stresses in general, other things being equal, tend to greater maintenance and repair cost and more rapid depreciation. Thus this item is to some extent proportional to the mechanical efficiency, and inversely proportional to the thermodynamic efficiency of the engine cycle.

The economic item of depreciation depends, however, not only on the wear of the apparatus, but also on the limitation of its useful life. In this respect it must be kept in view that with apparatus which is in a state of rapid development, as the steam turbine or the gas engine, the useful life should be expected to be shorter than with apparatus in a field in which no great development occurs. With a rapid advance in the development the time soon arrives where older apparatus is so far left behind as to make it more economical to replace it. This has been well illustrated by the history of the electrical industry. It would be an argument against the use of newer types of apparatus, and thus antagonistic to progress, if it were not for the fact that in the types of apparatus with which the new development competes the useful life is shortened in the same or probably still a greater degree, as either an extra rapid advance in their design must occur to meet the competition, or they would be replaced by newer types. Thus the useful life of the steam turbine, due to its rapid advance, must necessarily be shorter than the life of the steam engine would be if there were no turbine or gas engine; but due to the existence of steam turbines and gas engines, the useful life of the steam engine, as limited by the advance of the art, is correspondingly shortened, as it faces displacement by turbine or gas engine or also has to advance more rapidly.

It will be seen, therefore, that in the economic characteristics of thermodynamic prime movers in general, efficiency and the other features are to some extent mutually conflicting. Engineering judgment must therefore decide on the relative weights of the different economic factors which enter the choice of the prime mover in the individual case under consideration.

B. Reliability

Features, which are of importance for the reliability; that is, continuity of service, are:

1. The absence or presence of external influences beyond the control of the operating force, as meteorological effects, etc.

2. The design of the plant. This is an engineering problem outside of the scope of this paper. It is obvious, however, that an error in the design can rarely be remedied afterwards; therefore, before the plant is constructed and before the buildings are designed, the arrangement of prime movers and electrical apparatus should be designed to afford the greatest safety of operation. Frequently this has not been done. The architect of the buildings has overlooked the fact that the switchboards and controlling devices of our modern large, high-voltage electric plants require considerable space, and such apparatus—on which the safety of the system depends—has been crowded together in an altogether insufficient space, to the great detriment of the reliability of operation of the system. A marked improvement has taken place in this direction in the last years.

3. The probable frequency of shutdown of the prime mover, and the liability of involving other machines by it, and the number of other units and reserve plant available. To some

extent this depends on the mechanical and temperature stresses in the prime mover; it is related to the economic item of maintenance, repair, and depreciation.

4. Rapidity of starting of apparatus, and getting them into service, to cope with emergencies as a shutdown of the system or a part of it, as a breakdown of a transmission line or feeder, an accident to one or several units, etc., or even an unexpectedly rapid increase of load, and rapidity of reaction to changes of load; that is, speed regulation and voltage regulation, etc. These are important features in their effect on the reliability of service. They depend to a considerable extent on the type of prime movers and other apparatus, but to a still greater extent on the preparedness for such emergencies, and the organization of the operating force for it.

III.

The suitability of the different types of prime movers for the various economic and other requirements of electric service, as discussed above, are best seen by considering their characteristic features.

The available types of prime movers are:

A. The hydraulic turbine. The impulse type, the reaction type, and their various combinations.

B. The steam engine. Condensing and non-condensing, with and without superheat.

The steam turbine. Condensing and non-condensing, with and without superheat.

The gas engine. Using the available fuel directly, as natural gas, blast furnace gas or liquid fuel, and

The gas engine. With producer plant converting solid fuel into gas.

The gas turbine does not yet exist, but as it undoubtedly will arrive sometime, some consideration is given to it in the following.

A. Hydraulic Prime Movers.

The most prominent characteristic of hydraulic power is its dependence on meteorological conditions, dry seasons, freshets, ice in the water supply; and mechanical and electrical interference with the transmission lines connecting the power with its market. As a result the reliability of hydraulic power is inherently far below that of steam power. To give the same class of electric service, therefore, the reliability charge, in the form of duplication of plant, of steam reserve, etc., is far higher than with a steam plant close to its market. In this respect climatic conditions naturally exert a great effect.

The fixed cost is usually very high, due to the expensive hydraulic development required. It is especially high if water storage has to be provided; but this also depends largely on the local conditions of the water power.

The proportionate cost, is, however, very low, due to the absence of cost of fuel. This is the redeeming feature of the hydraulic plant, which gives it an advantage over steam power. Nevertheless, even with an extremely low proportionate cost, the high fixed cost and the high cost of reliability insurance greatly reduce the difference in the cost of steam power and of water power of the same quality. Under very unfavorable conditions, it may even make the water power more expensive than the steam power.

Owing to the high fixed cost and low proportionate cost, water power depends on a good load-factor still more than does steam power, to such an extent that it may occasionally be economical to oversell the water power, thereby keep constant load on it, and take care of peak loads, etc., by auxiliary steam plant.

B. THERMODYNAMIC PRIME MOVERS.

The thermodynamic efficiency is essentially a function of the temperature difference, on which the engine operates. The mechanical efficiency, maintenance cost, and reliability depend largely on the mechanical and temperature stresses in the prime movers, the available energy per unit weight and unit volume of the working fluid—steam or air—and on the speed of the engine.

To compare the different types of prime movers in this respect to determine how far certain features, as high mechanical stresses, low space economy, high thermodynamic efficiency, etc., are inherent in the type of prime mover, requires a study of their thermodynamic cycles.

In Fig. 1 is plotted, with the temperature in degrees centigrade as abscissas, the available energy in *K J* per kilogram of the working medium: steam or air, for the three typical air cycles, and for steam used non-condensing and condensing, in the latter case with a condenser pressure $p = 0.1$ kg. per cm^2, or about 27 in. vacuum; that is, about the average between that of the steam turbine and that of the reciprocating engine. The corresponding pressures are shown in dotted lines, and the thermodynamic efficiencies in the upper part of Fig. 1. Figs. 2 to 6 give some typical cycles, and Tables I and II the constants of these cycles.*

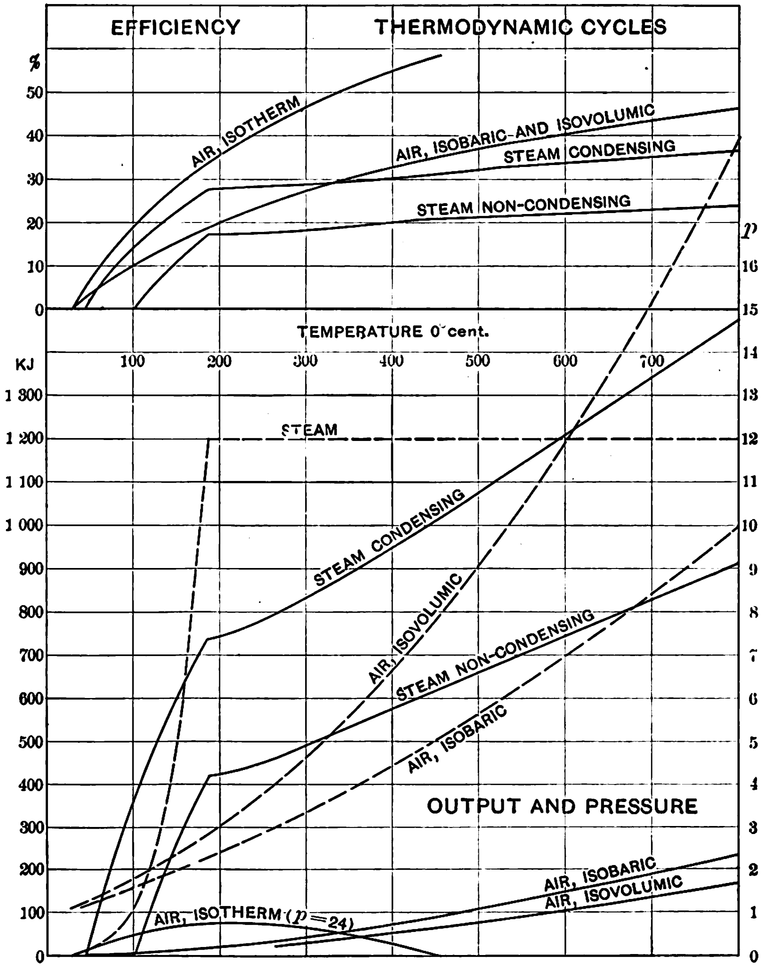

Fig. 1

A pressure limit of $p = 12$ kg. per cm^2 (about 170 lb. per sq. in.) is assumed for steam, while for the air cycles a maximum of twice this pressure has been allowed.

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* Obviously, these curves and tables are approximate only, as thermodynamic calculations do not allow of the same exactness as electric engineering calculations, since some of the essential constants, as the specific heat, the adiabatic constant, etc., are not yet known with the exactness familiar in electrical determinations.

As will be seen in Fig. 1, the isothermic or Carnot cycle; that is, constant temperature admission, adiabatic expansion, constant temperature exhaust, adiabatic compression, does not give any appreciable output, nor can it use considerable temperature differences without going to impracticable pressures. Thus its existence is limited to the text books of thermodynamics. With a maximum pressure $p = 24$, the maximum energy available for the Carnot cycle is 78 KJ per kilogram of air, or about one-tenth of the available energy of saturated steam at half this pressure, and occurs at the relatively low upper temperature of 225° cent. This cycle is shown in Fig. 2, and is the "fattest"

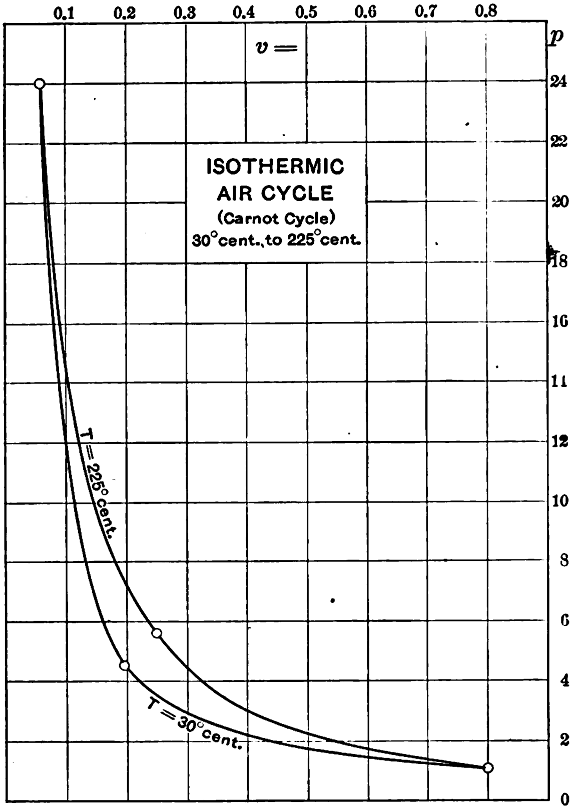

Fig. 2

Carnot cycle which can exist within the pressure limit of 24 kg. per cm^2. At higher temperatures the efficiency of the Carnot cycle increases, but the output decreases; the output vanishes, by the cycle collapsing into a line, at about 455° cent., or at a temperature far below that permissible in gas engines.

The curve for the isovolumic air cycle; that is, constant volume admission (constant volume combustion) and constant volume exhaust is the cycle of the theoretical or ideal gas engine. The curve for the isobaric cycle; that is, constant pressure admission and constant pressure exhaust would be the cycle of the gas turbine. These curves are calculated for the conditions of maximum available energy between the given temperature limits. Under this condition the thermodynamic efficiency is much lower than the maximum possible thermodynamic efficiency as represented by the Carnot cycle. It is: $\eta = 1 - \sqrt{\frac{T_2}{T_1}}$ for the isovolumic as well as the isobaric cycle of maximum energy, while the efficiency of the isothermic cycle is $\eta = 1 - \frac{T_2}{T_1}$,

where T_1 is the maximum, T_2 the minimum absolute temperature reached during the cycle. The thermodynamic efficiency of these cycles can be increased by going to higher pressures, but the output and thus the mechanical efficiency are decreased thereby.

It is interesting to note that the available energy of the air cycle per kilogram of air is insignificant until higher temperatures are reached; but even at a temperature of 800° cent. it is still much lower than that of the non-condensing steam cycle. It must be considered, however, that the volume of steam per unit weight is 58 per cent greater than that of air at the same temperature and pressure. The thermodynamic efficiency of these cycles is less than that of the steam cycle for lower temperature, but rises far above it at higher temperatures.

The relatively low pressure is interesting. This pressure gives the maximum output in an isobaric air cycle, and shows that the development of the gas turbine will take place at relatively moderate pressures.

In Figs. 3 and 4 are shown the isovolumic and isobaric cycles for 800° cent. maximum temperature and the same conditions of maximum available energy as in Fig. 1. Obviously, the high-pressure peak at the beginning of the expansion, in Fig. 3, is cut off by delayed combustion, etc. Even at the highest temperature the maximum output pressure of the isovolumic cycle does not reach that occurring in the Carnot cycle at an insignificant output.

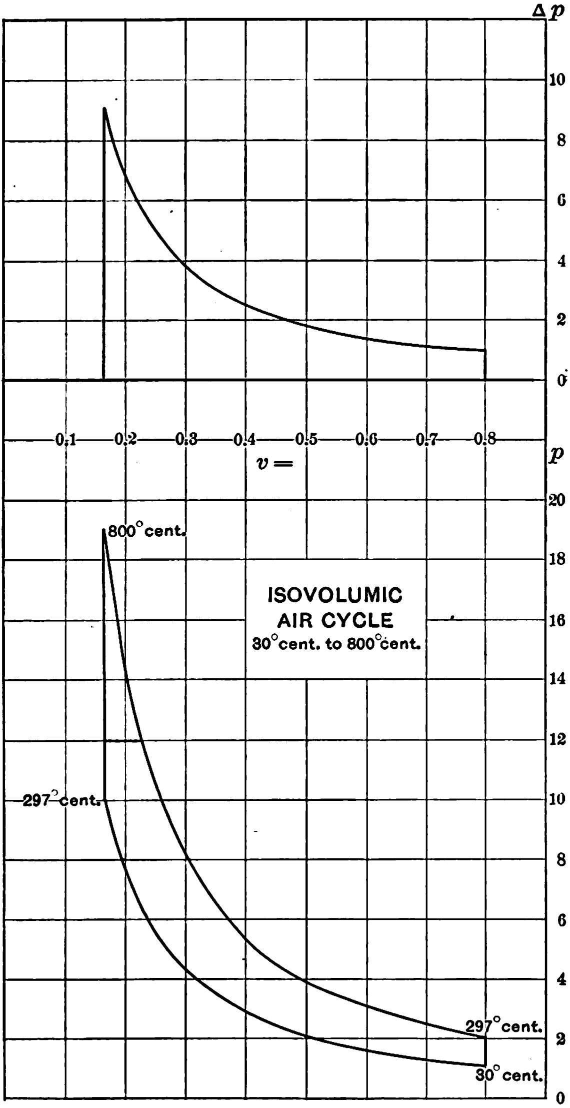

FIG. 3

The steam curves in Fig. 1 are interesting by the very rapid rise and very high values of available energy. Thus in the temperature interval of 141° cent., between boiler and condenser temperature, the steam cycle gives per kilogram more than four times the available energy of the isovolumic air cycle in the temperature interval of nearly 800° cent. Obviously, the cause is the partial condensation of the steam, which makes the enormous latent heat of steam available.

The efficiency of the saturated steam cycle is virtually the same as that of the Carnot cycle; that is, the theoretical maximum possible for the utilized temperature interval. However, the pressure rises very rapidly, and the temperature interval which can be used in the saturated steam cycle is limited thereby. Hence from the temperature of 187° cent., corresponding to the steam pressure of $p = 12$, the further increase of temperature occurs not at saturation and with rising steam pressure, but at constant steam pressure, by superheat.

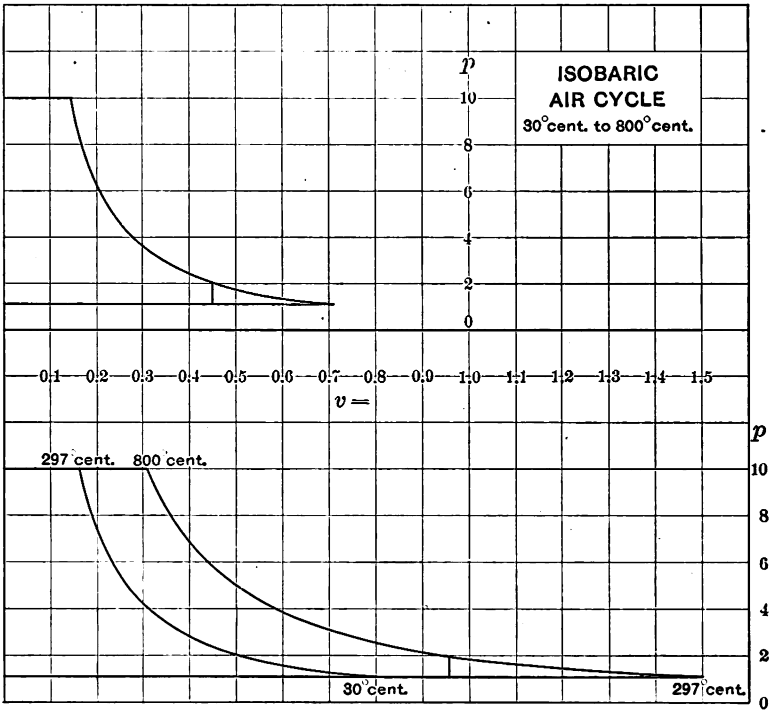

FIG. 4

These curves of superheated steam* show the small increase of available energy of superheat, until very high superheats, gas-engine temperatures, are reached. They show especially the very small increase of thermodynamic efficiency resulting from superheat. Thus doubling the temperature range (141° cent.), of condensing saturated steam, by 141° cent. superheat increases the available energy only by 17.5 per cent, and the efficiency by 1 per cent. Increase of the temperature range of steam by superheat, therefore, does not increase the thermodynamic efficiency of the cycle correspondingly, and the steam cycle, while more efficient than the air cycle at low temperature, drops below it in thermodynamic efficiency at higher temperature. While the efficiency of the temperature range beyond saturation temperature is higher in accordance with the thermodynamic laws, the amount of work done in this range is such a small part of the total work that it does not appreciably increase the total efficiency.

The increase of efficiency of the steam cycle by superheat is not due to an increase of thermodynamic efficiency of the cycle, but is due to the decrease of losses, mainly those resulting from the condensation of moisture; that is, it is essentially an increase of what has previously been considered as mechanical efficiency.

The available energy of superheat becomes considerable only at very high temperatures, and the thermodynamic efficiency, therefore, increases. However, for the total range from boiler temperature of 187° cent. to gas-engine temperature of 800° cent., the additional available energy of superheat about equals that of the steam in the 141° range below saturation, and the thermodynamic efficiency rises by only 9 per cent., thus drops far below gas-engine values. This is important as indicating the losses of thermodynamic efficiency, resulting by limiting the temperature of combustion in gas cycles by injecting water.

Beyond the point marked by a circle on the steam curves, the steam remains superheated even at exhaust pressures; that is, the cycle occurs entirely within the gas range. Obviously, this point is shifted to lower temperatures in the turbine engine by the re-evaporation of moisture by mechanical losses.

It is interesting to note the large amount of available energy of steam below atmospheric pressure, 350 KJ per kilogram of steam, which is used in the low-pressure steam turbine.

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* Calculated with the specific heat $c_p = 0.525$ at $p = 12.$ and the adiabatic constant $a = 1.286$.

Fig. 5 gives the cycle of non-condensing saturated steam, and Fig. 6 the turbine cycle of condensing saturated steam.

Comparing Figs. 4 and 5 illustrates the greater width of the area of the steam cycle. In Figs. 3, 4, and 5 the cycle is shown in the upper part of the Fig., modified by subtracting the compression curve from the expansion curve, as this gives the area and thereby the available energy in a form more convenient for comparison.

Characteristic of all thermodynamic cycles, Figs. 4, 5, 6, is the very large volume at the end of the expansion; that is, the area runs out in a long and low triangular shape. To carry the adiabatic expansion down to exhaust pressure, therefore, would require abnormally large cylinder volumes in a reciprocating engine, and correspondingly larger mechanical losses; therefore the expansion has to be broken off long before exhaust pressure is reached, about as indicated in the curves, or even at still higher pressures. As a result the reciprocating engine cannot get the full benefit of very low condenser pres-

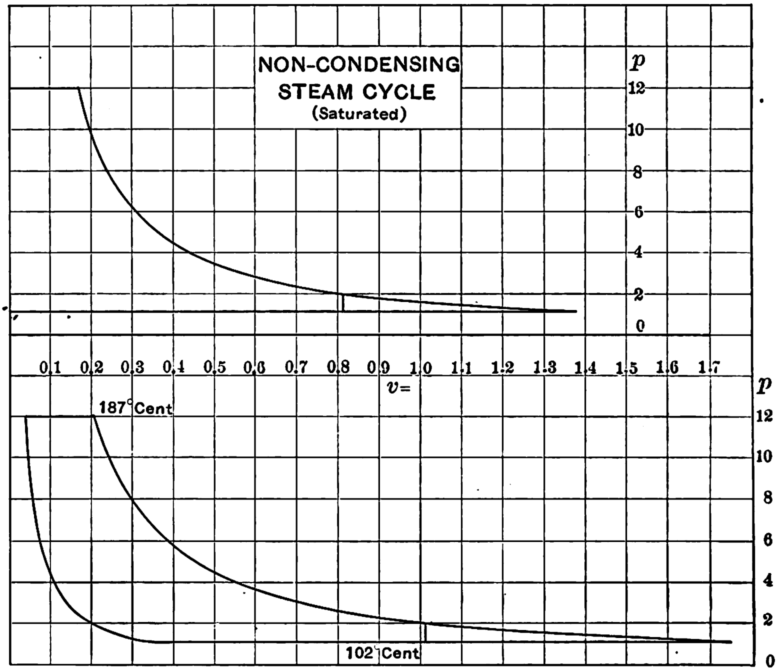

FIG. 5

sures, while the turbine engine is not limited in this respect. For instance, between $p = 0.07$, or 28 in. vacuum, and $p = 0.2$, as the pressure at the end of the expansion of a reciprocating engine, the available energy per kilogram of steam is 153 *K J*, or about 37 per cent of the total energy of the non-condensing steam cycle. Of this only 100 *K J*, or about two-thirds is used is the steam engine, while the total is used in the turbine. Hence the steam turbine gains far more by high condenser vacuum than the reciprocating engine. With a steam turbine of condenser pressure $p = 0.07$ (28 in. vacuum) the available energy of the steam would be higher by 42 *K J*, than the steam curve in Fig. 1.

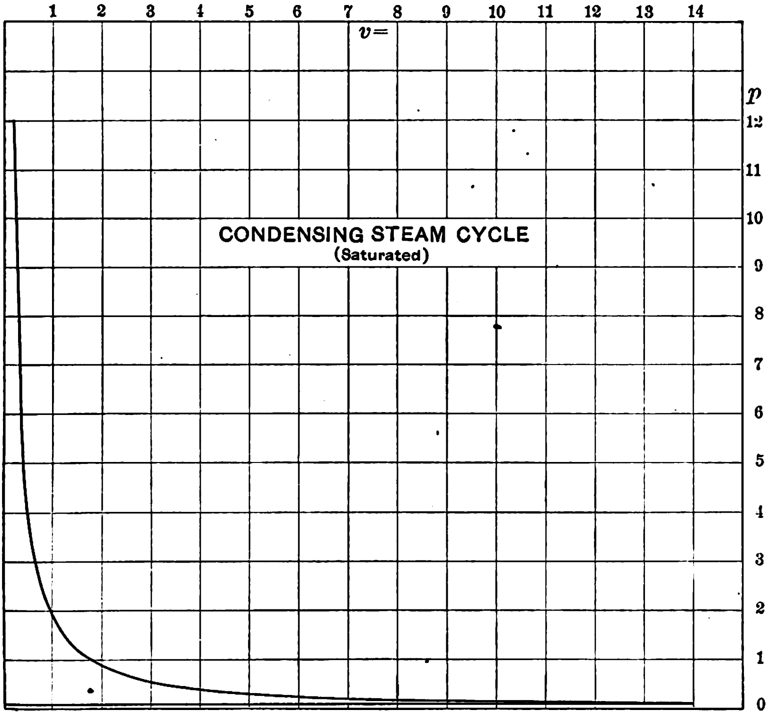

FIG. 6

To show the relative magnitude of the quantities, the results of six typical cycles are calculated in Tables I and II.

As seen from Table II, the available energy *E* per kilogram of working medium is highest for steam with condensation, lowest for the Carnot cycle of air. The weight *w* of steam or air, required per 1000 $K\ J$ of available energy, is given in column 6, and varies between 0.68 kilogram for steam superheated to 800° cent., and 12.8 kg. for the Carnot cycle. Column 7 shows the maximum volume v_0, per 1000 $K\ J$, assumed by the working medium at the end of the expansion. Here 2*a*, 3*a*, and 4 are such as to show the impracticability of these cycles for an engine in which the maximum volume is of importance; that is, a cylinder engine. Cycles 2*a* and 3*a* thus are turbine cycles.

TABLE I.

THERMODYNAMIC CYCLES

1. *Saturated steam, non-condensing.* Fig. 5.
    a. Expanding from: $p_1 = 12$; $v_1 = 0.166$; $T_1 = 187°$ cent.
    to: $p_2 = 1.1$; $v_2 = 1.38$; $T_2 = 102°$ cent.
    b. Expansion terminated at: $p_1' = 2$; $v_2' = 0.81$
    c. Compound engine, low-pressure cylinder: $p_1' = 3.5$; $p_2 = 1.1$
2. *Saturated steam, condensing.* Fig. 6.
    a. Expanding from: $p_1 = 12$; $v_1 = 0.166$; $T_1 = 187°$ cent.
    to: $p_2 = 0.1$; $v_2 = 11.5$; $T_2 = 46°$ cent.
    b. Expansion terminated at: $p_2' = 0.2$; $v_2' = 6.2$
    c. Triple-expansion engine. Expansion terminated at: $p_2' = 0.2$; $v_2' = 6.2$. Low-pressure cylinder: $p_1' = 0.8$.
3. *Superheated steam of Gas-engine temperature*, 800° cent.
    a. Expanding from: $p_1 = 12$; $v_1 = 0.38$; $T_1 = 800°$ cent.
    to: $p_2 = .1$; $v_2 = 17.5$; $T_2 = 98°$ cent.
    b. Expansion terminated at; $p_2' = 0.2$; $v_2' = 9.4$
    c. Triple-expansion engine. Expansion terminated at: $p_2' = 0.2$; $v_2' = 9.4$. Low-pressure cylinder: $p_1' = 0.8$.
4. *Air, isothermic,* (*Carnot*) *cycle.* Fig. 2.
    Expanding from: $p_1 = 24$; $v_1 = 0.06$; $T_1 = 225°$ cent.
    to: $p_2 = 1.1$; $v_2 = 0.8$; $T_2 = 30°$ cent.
5. *Air, isobaric cycle.* Fig. 4.
    Expanding from: $p_1 = 10$; $v_1' = 0.31$; $T_1 = 800°$ cent.
    to: $p_2 = 1.1$; $v_2 = 1.5$; $T_2' = 297°$ cent.
    Compressing from $p_2 = 1.1$; $v_2' = 0.8$; $T_2 = 30°$ cent.
    to: $p_1 = 10$; $v_1 = .166$; $T_1' = 297°$ cent.
6. *Air, isovolumic cycle.* Fig. 3.
    Expanding from: $p_1 = 19$; $v_1 = 0.166$; $T_1 = 800°$ cent.
    to: $p_2' = 2.1$; $v_2 = 0.8$; $T_2' = 297°$ cent.
    Compressing from: $p_2 = 1.1$; $v_2 = 0.8$; $T_2 = 30°$ cent.
    to: $p_1' = 10$; $v_1 = 0.166$; $T_1' = 297°$ cent.

At the same piston speed; that is, the same number of revolutions and same piston stroke, the product of maximum pressure (column 4) and maximum volume (column 7) is proportional to the piston pressure, and these relative piston pressures: $P = p\,v_0$, are given in column 8. This column is an indication

TABLE II.

			Thermodynamic Cycles.								
1	2	3	4	5	6	7	8	9	10	11	12
Available energy per kg.	Thermo-dynamic efficiency	Maximum			Per 1000 $K J$ available energy		Relative piston pressure $P = p v_0$	Per 1000 kw. output, at 60% resp. 50% mechanical efficiency, 60% boiler and furnace efficiency, double-acting engine 75 rev. per min.			
$K J$	%	Temperature ° cent.	Pressure kg per cm²	volume m³ per kg.	Weight kg.	Max. volume m³		Cylinder Volume		kg. per kw. hour. steam or air	Total Efficiency
								m³	$c b$ ft.		
E	η	T	p	V	w	v_0		V		W	
		1. Non Condensing. Saturated steam. *a.* Turbine Cycle.									
416	17.4	187	12	1.38	2.40	3.32	39.8	2.21	78	14.4	6.3
		b. Engine Cycle.									
395		187	12	.81	2.53	2.05	24.6	1.37	48	15.2	6.1
		c. Low Pressure Cylinder of Compound Engine.									
416		138	3.5	1.38	2.40	3.32	11.6	2.21	78	14.4	6.3
		2. Condensing. Saturated Steam. *a.* Turbine Cycle.									
734	27.8	187	12	11.5	1.34	15.7	188	10.5	370	8.0	10.0
		b. Engine Cycle.									
715		187	12	6.2	1.40	8.7	104	5.8	205	8.4	9.8
		c. Low Pressure Cylinder of Triple Expansion Engine.									
715		93	0.8	6.2	1.40	8.7	7.0	5.8	205	8.4	9.8
		3. Condensing, Steam Superheated to Gas Engine Temperature (800° C.) *a.* Turbine Cycle.									
1480	37.0	800	12	17.5	0.68	11.8	142	7.9	280	4.1	13.3
		b. Engine Cycle.									
1460		800	12	9.4	0.69	6.4	77	4.3	152	4.2	13.1
		c. Low-pressure cylinder of Triple Expansion Engine.									
1460		300	0.8	9.4	0.69	6.4	5.1	4.3	152	4.2	13.1
		4. Isothermic air cycle. (Carnot cycle.)									
78	37	225	24	0.8	12.8	10.3	247	8.2	290	92	18.5 (14)
		5. Isobaric Air Cycle. (Turbine Cycle.)									
240	47	800	10	1.5	4.17	6.25	62.5	5.0	176	30	23.5 (17.6)
		6. Isovolumic Air Cycle. (Engine Cycle.)									
172	47	800	19	0.8	5.83	4.65	84	3.7	130	42	23.5 (17.6)

In a turbine engine, at 135 m sec. wheel-speed, the maximum section of the steam passages, (at the exit side of the last low-pressure wheel) would in 2*a*, the condensing steam turbine of exhaust pressure $p = 0.1$, be only 1400 cm², or 1.5 sq. ft., against 370 resp. 205 cu. ft. cylinder volume, per 1000 kw. output.

In a gas turbine, 5, the maximum outflow section under the same conditions would be only 660 cm², or less than 0.75 sq. ft., compared with 130 cu. ft. cylinder volume in 6, per 1000 kw. output.

of the mechanical strains which have to be taken care of in the engine design.

Column 8 shows the impracticability of utilizing the full pressure range of a condensing steam engine in a single cylinder-even if it were otherwise permissible—due to the excessive piston pressure resulting in this case; it also shows the enormous reduction of piston pressure by subdivision of the expansion—from 24.6 to 11.6 in the compound, non-condensing engine, and from 104 to 7.0 in the triple-expansion, non-condensing engine with saturated steam. Very striking, however, are the much higher piston pressures of the air cycle; that is, the gas engine: 84 in the isobaric and 62.5 in the isovolumic cycles, compared with 7 in the condensing, triple-expansion steam engine. While by different assumptions, regarding pressure, temperature, etc., the numerical values may be considerably varied, the differences between the two types of engines are of such magnitude as to exhibit a characteristic or inherent feature of the cycles.

In the last four columns are given, for 1000 kw. output, the values of cylinder volume, in m^3 and cu. ft., of kilogram of steam or air consumed per kilowatt-hour, and the total efficiency, under the assumption of 60 per cent mechanical efficiency of the steam cycle and 50 per cent mechanical efficiency of the air cycle*, for a double-acting engine of 75 rev. per min., under the assumption of 60 per cent boiler and furnace efficiency; that is, ratio of heat units supplied to the engine to heat units representing the chemical energy of the fuel. The efficiencies of the air cycles are given for 100 per cent producer efficiency; that is, the case of gaseous or liquid fuel. In brackets are added the efficiencies for a plant making its gas from coal, by assuming 75 per cent producer efficiency.

Table II shows the characteristic and inherent differences between steam engine, steam turbine, and gas engine. The steam turbine can utilize the expansion as far down in pressure as condenser design permits, and is of smaller size than the steam engine, due to the higher velocities permissible by the rotary motion.

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* By mechanical efficiency is understood the ratio of mechanical output to the available energy of the cycle. The mechanical efficiency thus includes all of the losses between the available energy and the indicated engine output, as condensation, radiation, delayed combustion, throttling, steam friction, etc., which are not included in the ratio of brake horse power to indicated horse power.

Characteristic of the gas engine, compared with the steam engine, are higher piston pressures, thus heavier reciprocating masses, and thereby heavier construction, larger sizes, and greater mechanical losses, and lower space economy, especially when compared with the steam turbine. From the higher mechanical stresses inherent to the gas engine must be expected a lower reliability of service, or a higher class of the required attendance, or a more difficult and expensive engine design. Also characteristic of the gas-engine cycle is a very much higher thermodynamic efficiency which, even when allowing for the lower mechanical efficiency resulting from the higher mechanical stresses, is still very far above that of the steam engine, especially when gaseous fuel is directly available, and no producer plant is required.

In general, however, in discussing gas engines, the two distinctly different cases must be separated:

a. Where gaseous or liquid fuel is available, as in the blast furnace gas, natural gas, the automobile engine.

b. Where gaseous fuel has to be produced from coal by a separate plant.

When balancing the advantages of higher efficiency against the disadvantages resulting from the higher mechanical stresses, the difference between the two cases may often be the determining feature in the choice of the prime mover for maximum total economy.

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ELECTRIC HEATING

BY W. S. HADAWAY, JR.

It may assist in a better understanding of the terms used in discussing electric heating to state at the outset that the words heat, potential, etc., are employed more specifically than has generally been found necessary in discussing heat effects apart from electricity. Heat, like electricity, is assumed to flow from a surface of high potential to one of low potential. Quantity or volume of heat is analogous to quantity of electricity. Unit quantity is here figured as the British thermal unit, though for technical purposes it is, of course, the calorie. Temperature corresponds to potential. Heat potential is as true an expression of potential as is impressed electromotive force; it should not, however, be confounded with static potential, a term used in discussing energy of gas. It would materially simplify thermal nomenclature if a word were coined to designate heat potential in the same manner that electromotive force expresses electrical potential.

The term " electric heating " is commonly used to express the frittering down of the higher potential energy of electricity into the lower potential energy of heat. There is no well defined line of demarcation; the result is inseparable from the conveyance or utilization of electricity in any degree. The expression is, therefore, a meaningless one from the heat engineer's standpoint and it fails accurately to express the performance of useful work by the transmission of heat energy to a distance by means of electricity. The expression, " electricity, a factor in a telethermic system," would be a better definition, but for obvious reasons the shorter and simpler expression is employed.

Heat energy is to be regarded as a commodity that can be generated or controlled in convenient form and distributed and sold, and in which electricity is used either directly as the high-potential heat factor or indirectly as agent. The distribution and application of heat energy by electricity to arc and incandescent lighting, to metal welding and forging, and to electric furnaces for various industrial operations are illustrations of results already attained in electric heating and are properly discussed under the broad interpretation of the subject.

The feature of the subject we are to consider is the practical adaptability of commercial electricity for heating purposes and for performing useful work under the conditions imposed in general industrial and domestic life, apart from the specific adaptations previously mentioned, and particularly in connection with other heat distributors for a multipotential heat supply.

These applications may be roughly divided into two classes according to the degree of concentration of the heat energy used. The first class includes low-temperature heating, generally diffused and in large volume; the second includes high-temperature heating, generally localized and in small quantity.

In heating on a small scale no adequate classification is possible; it is the blending of high-potential heat energy into low-potential heat work for many useful operations that primarily suggests the feasibility of heat transmission by electricity. An arbitrary line of temperature demarcation for heating on a large scale has been drawn at 250° fahr.

The closest common analogy to the differences between low-potential, large-volume and high-potential, small-volume heating is the distinction between volume and pitch in sound. As examples of the first class may be cited the heating of rooms and of water at atmospheric pressure; examples of the second class are electric ovens, sad-irons, and soldering-irons.

The electrical unit or kilowatt-hour is the equivalent of 3412 British thermal units. For practical purposes the work in hand is to determine the useful work in different lines obtainable from this number of heat units at a fair average cost of supply. There is involved indirectly the determination of relative efficiency between electric and other methods of heat generation, distribution, and application.

To show what the heating efficiency of different methods of application may mean, the following experiments, reviewed in the London *Electrician* for Nov. 2, 1894, are cited. The determinations were the relative heating values of combustion and electricity by resistance. The same wires were heated, first in a flame and then by electric current. It was found that with a platinum wire held in a flame less than 0.5% of the thermal energy produced in the flame was transferred to the wire, while 90% of the electrical energy used appeared as heat. In another case an iron bar weighing about 20 lb. was heated by charcoal and then by electricity. In the former case about 0.75% of the thermal energy was transferred to the bar and in the latter case 88%. It is evident from the description that the calorimetric methods employed were rough, and the results are quoted more as qualitative than quantitative determinations.

It should be observed that the foregoing illustrations are examples of the second class of heating applications; figures tabulated farther on will show results obtained in water heating by various methods of heat application, which are as true examples of efficiency tests as the preceding but in the first class of heating. The heat capacity of the work performed is sufficiently large to express the relative differences in combined efficiency, and, as we should expect, the lower the temperature of the work, the larger the area heated; and the greater the capacity the less the difference in ratio between heating by combustion and by electricity. We may readily determine the conditions where the ratio is an inverse one.

In room-heating apparatus on continuous run we may estimate that one watt-hour, 3.41 thermal units, will heat one square foot of common radiator surface through 1.26 degrees fahr.; that 1000 watt-hours or 3412 thermal units will heat the surface approximately 126 degrees fahr. above the room temperature; that is, for room heating from 85 to 110 watt-hours are practically the equivalent of steam at low pressure condensed by one square foot of radiator surface with the difference between the room and the radiator temperatures as above stated. This, of course, takes no account of the heat capacity of the apparatus, which is practically eliminated by the imposed conditions of continuous running. We may safely assume that a fair average price of the electrical unit from large steam electric stations is 6.7 cents. It would therefore cost 0.65 cents average to run one square foot of direct radiation surface for one hour, or the electrical unit would keep about 10.3 sq. ft. of radiator surface at the temperature difference noted for one hour.

Direct comparison of this value with practical steam heating is difficult, owing to the variables involved. We may, however, compare it with a central station steam distributor as quoted by Unwin in his work on the " Development and Transmission of Power," referring to a New York steam company.

The unit of heat used by this company is defined as the " kal ", which is stated to be the heat required to evaporate one pound of water from 100° fahr. at 361° fahr. or at 85 lb. pressure per square inch. One kal is therefore about 1110 thermal units. On a sliding scale the charge is stated to be 70c. per 1000 kals to small users, and 40c. per 1000 to large users. As the price of 6.7c. per electrical unit is to a fairly large user, we shall compare it with the 40c. per 1000 kal rate. For 40c. the consumer obtains 1,110,000 thermal units from the steam station, compared with 20,400 thermal units from the electric station, a ratio of nearly 54 to 1, or practically 50 to 1 as a loss must be figured in the case of steam, dependent upon the temperature at which the condensed water is allowed to escape.

It is interesting to note in passing that while the relative efficiencies of generation are about as 12 to 1, the commercial rates quoted are as 50 to 1. The ratio of the cost of heat energy from the electric station to the cost from the steam station is therefore practically four times as great as the ratio of the relative costs of production. This disparity should be considered in discussing the influence and importance of the load-factor as discussed by Crompton in his paper on " Electric Energy."

Clearly, the steam-driven electric light station ranks low as a heat distributor for house warming on any considerable scale. And yet notwithstanding the great disparities in the cost of heat energy on a large scale, the uses to which small electric air heaters are put are surprisingly numerous. We are all more or less familiar with the use of gas stoves for room warming, but it has been found by wide experience that the electric air heater for auxiliary room warming, for bath and dressing rooms, for libraries, cabins on yachts and steamships, in mild climates in early morning and evening, etc., serves its purpose with fair economy, and without vitiation of the air and by-products always evident from gas.

It is then on a comparatively small scale and in intermittent service that the electric air heater is useful when power is derived from the steam electric station and when the heat supplied is derived from the electric resistance. It is interesting to note that the relative costs of copper and structural steel differ in nearly the same proportion as the generation costs of electricity and steam. And while we use steel as the frame-body, and copper to round out and embellish the structure, so may the relative value of electricity to steam be regarded in heavy quantitative heating work.

This discussion does not include heat storage systems from hydroelectric installations which have been described briefly by Mr. Chas. E. Waddell*. Where an equipment is utilized for only 50% to 60% of the day, and water storage is not required, there are opportunities for broadening out electric heating applications by absorbing the energy of the plant in heated water, which may be employed in combination with high-temperature heaters at periods where under other conditions the loads would overlap. It is evident that this method of supplying the low-temperature component of a heating system must be resorted to before electric cooking, which includes hot water in considerable volume, can be generally successful.

While considering the use of electricity in diffused heating on a large scale, we should not overlook the deductions made by Lord Kelvin " On the Economy of the Heating or Cooling of Buildings by Means of Currents of Air " and published in the Glasgow *Philosophical Proceedings* Vol. III for Dec. 1852 and followed by mathematical demonstrations in the Cambridge and Dublin mathematical journal for Nov. 1853. Quoting from these articles:

> In the mathematical investigation it is shown that according to the general principles of the dynamical theory of heat any substance may be heated 30 degrees above the atmospheric temperature by means of a properly contrived machine driven by an agent spending not more than about 1/35 of the energy of the heat thus communicated and that a corresponding machine or the same machine worked backward may be employed to produce cooling effects, requiring about the same expenditure of energy in working it to cool the same substance through a similar range of temperature. When a body is heated by such means about 34/35 of the heat is drawn from surrounding objects and 1/35 is created by the action of the agent; and when a body is cooled by the corresponding process the whole heat abstracted from it, together with a quantity created by the agent, equal to about 1/35 of this amount is given out to the surrounding objects.

We have thus introduced refrigeration as well as heating by electricity as agent. In editing his mathematical and physical papers, Lord Kelvin added the following interesting note under the date of June 26, 1881:

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* Proceedings A. I. E. E., July 1908, p. 1197.

The method of cooling air in unlimited quantities described in this article has been realized by Mr. Coleman, first in refrigerators used for the distillation of paraffin and after that in the Bell-Coleman refrigerator for carrying supplies of fresh meat from North America to Europe; in a great refrigerator recently sent out for the Abattoir at Brisbane, Queensland. The Bell-Coleman machine sends large quantities of air cooled to 10° or 20° C. below the freezing point into the chamber to be kept cool; and the general temperature of this chamber is thus maintained at the desired point.

The method of heating air described in the article remains unrealized to this day. When Niagara is set to work for the benefit of North America through electric conductors it will no doubt be largely employed for the warming of houses over a considerable part of Canada and the United States. But it is probable that it will also have applications, though less large in other cold countries to multiply the heat of coal and other fuels, and to utilize wind and water power (with aid of electric accumulators) for warming houses.

In Anderson's treatise on the "Conversion of Heat into Work,"* will be found descriptions of compressed air refrigerating machines made on the principle above described, and in Professor Peabody's work on the "Thermodynamics of the Steam Engine," pages 464 and 465, will be found tests on a Bell-Coleman refrigerating machine. The use of electric motors in refrigeration has been under consideration of central station men for some time, being advocated by well known engineering authorities; but so far as the writer can learn nothing whatever has been accomplished in the use of motors for heating purposes.

Lord Kelvin's deductions on using electricity as agent for warming purposes have been advisedly introduced into this discussion. His conclusions may prove to be wrong until more perfect thermal insulation is developed, but to anyone familiar with thermodynamics and electrical development the possibility of using a positive force to control and direct a less definite form of energy must appeal with singular emphasis.

It may be that the electric furnace using low-grade carbon in high-temperature combustion chambers will give the desired results. Tests indicate that the only obstacle to this latter combination is in making the apparatus "fool-proof." The need for more economical use of fuels and the fact that electricity by resistance heaters is an ideal high temperature component make the development of the low-temperature factor imperative for a complete combination.

When electricity is derived from water power we might expect a far wider availability of energy from heat of resistance for applications requiring heat in large volumes than when electricity is derived from steam power. Careful deductions show that for house warming the cost of a horse power year must not exceed $6.00 in order to compete directly with high grade coal at $5.00 per ton.

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* Third edition, pages 189 and 194.

Statistics compiled by Professor Geo. F. Swain show that the average cost of the mechanical horse power-year from water power in this country is about $10.00; to this must be added electrical generation and transmission charges, which make it seemingly impossible to realize a figure for electrical energy delivered that will not be greater than the cost of heat directly from fuel. The compensating advantages in regulation and control, combined with the improved load-factor, especially in combination with thermal storage work, warrants the extensive use of the heat of resistance for house warming at least within restricted areas. In the case of hydraulic plants with large water falls, where the capital charges are relatively low, we may expect many extensive applications of room heating on a successful basis.

In his paper on "The Cost of Steam Power",* Mr. C. E. Emery cites the case of Lawrence, Mass., where with moderate fall the cost of a horse power-year from water power is figured at about $25.00, or practically the same cost as power generated from steam. In the practical treatment of this question, local conditions will control the breadth of applicability, including in these local conditions cost of electric power, cost of coal delivered, extremes of climate, average humidity, etc.

We have still another source of electrical energy to consider in connection with low-temperature diffused heating, in which power is derived from gas, oil, and air engines. In a lecture before the Royal Institution in April, 1893, on the "Utilization of Energy," Professor Kennedy places the theoretical efficiency of coal gas at 80%. Of this a gas engine, he says, utilizes from 22% to 32%. For diffused heating it is apparently more economical to distribute the gas directly than to attempt to convert its energy into electricity. Attention is further called to the paper by Mr. Williams before the Society of Arts, Boston, Mass., on May 10, 1894, in which comparative costs of coal and various fuel gases are given, and in which it is shown that the gas equivalent of coal may, under most favorable circumstances, cost eight or ten times as much as coal.

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* Transactions A. I. E. E., March 1893.

The consideration of the relative values of gas and electricity for heating purposes is a matter that can only be inadequately discussed here, for the problem is a complicated one and demands the most thorough consideration. We must not underrate the facility with which gas may be stored, the economy of rapid and continuous generation, and available heat from combustion and discharge of by-products, whereas in electric lighting and electric heating every unit of light and heat secured represents an appreciable loss or depreciation of the energy converter.

There are many advantages to be considered on the other side such as localization, immersion of heater in working chamber, as in ovens, sad-irons, and water heaters, freedom from bi-products, etc. In electric heating and cooking for domestic uses the real difficulty is how to provide a hot-water supply economically. The same thing is true in the use of gas, though in a lesser degree. On a broad scale it appears easier to arrange for this on a multipotential heat supply system than on any system using gas.

In his treatise on gas engines, Donkin shows examples of these engines of large size furnishing power at rates less than can be obtained from other prime movers. For high-potential heat distribution from isolated plants this form of energy transmitter is generally available; but it may be seriously questioned whether in isolated plants for domestic use the hot water supply as usually provided can be economically heated, unless of course the combined economies permit the use of individual gas-heated water supplies.

It may be safely concluded from the foregoing illustrations that we cannot afford to use electricity for general diffused heating purposes on a large scale. It is proper to point out, however, that practical experience shows that these deductions may lead to unsafe conclusions. There are many striking analogies in heating development to the working out of the electric motor.

If we were to take the case of an engine in a factory and substitute for it an electric motor we would not expect, with our present knowledge of this subject, to effect marked economies. We know that we depend upon the elasticity of the small motor to produce results and that the combined load of a number of individual units reduces fixed losses and increases output. It is the same in heating. We must consider the individual applications, and the combined results of these will be far different from any considerations controlling a fixed system. One of the reasons contributing to the slow growth of electric heating development is the necessity in many cases of devising apparatus to do work more effectively than could be done by the old methods.

On the other hand, the collective strength of these new methods has given the work a standing, in the industrial lines particularly, which constitutes an advance in heating development. It has further been shown that results may be obtained which make the cost of operation of secondary importance than if considered solely on basis of thermal values.

The British thermal unit is the equivalent of 778 foot-pounds of work, and we would obtain as much heat by applying a brake directly to the fly-wheel of the engine or prime mover as we obtain from the heat of electrical resistance, which so far as its results go may be considered as friction. If we use as an average thermal value of a pound of coal 14,500 B.t.u., we can secure 9400 units in a good steam boiler, or practically 65%.

There are many cases in practice in which this efficiency is exceeded, but Thurston's figures give 65% as a fair average value. The fuel efficiency of the steam engine rarely exceeds 10%, and the heat incapable of conversion into high-potential energy represents about nine-tenths of the whole, notwithstanding the fact that over six-tenths of the thermal energy of the coal are obtained in useful work in the boiler.

It is therefore to this point we should look for our large volume heat supply, and we find in actual practice many illustrations which show that no great engineering difficulties are encountered in distributing the boiler energy and also that of the exhaust steam from the engine for useful work at a distance. The New York steam company's plants already referred to are distributing energy by live steam for heating and power purposes at about 80 lb. pressure. The leakage and radiation losses are stated to be estimated at about 15%, yet with this loss the heat energy can be delivered on a successful and economical basis.

The work of Birdsill Holly since 1877 in carrying out central station heat supply is too well known to require explanation. It is important and interesting in connection with our problem since it shows that central station diffused heat supply is entirely feasible. We are now able to formulate a multipotential heat supply system in which the steam, either live or exhaust, or both, is used for low-temperature work, and electricity from generators in the same station is employed for all work requiring temperatures in excess of that of the steam; that is, from about 250° fahr. upward. In domestic work the steam heat would be employed for house heating and water heating for bathing, laundry, and cooking purposes. Electric heat would be used for lamps, ovens, broilers, small stoves, sad-irons and all purposes requiring a high temperature localized heat. And a feature of such a combination not to be overlooked is the facility with which ventilation and heat regulation can be secured, since all the elements are at command to force an abundant supply of heated pure air through the building to be warmed. There are no new or untried features in such a combination; practically all of the elements necessary for the work are already employed though in a somewhat disjointed form so far as complete flexibility of heat supply from one center of distribution is concerned. If we refer to the *Electrical Engineer* for April 5, 1893, there will be found a description of the Springfield (Ill.) electric light and steam distribution plant. In operating this plant the exhaust steam is used for warming buildings, but there appeared to be no systematic effort made to carry out a multipotential heat supply.

As bearing upon the historical development of this matter the author quotes from a letter from the American District Steam Co., of Lockport, N. Y., in 1894:

> We observe that you recognize the futility of electricity competing with steam for diffused heating, but there is a wide field for electrical companies in connection with their exhaust. In blocks of buildings where power is required to run elevators, or for other purposes, the proprietors will run their own power if they have to do their own heating, but if the electric company can heat the building it can get the power at a good profit and there is a profit in both heating and power.
>
> We have just constructed a heating plant for the Rochester (N. Y.) Gas & Electric Co., who are doing just this thing; they start off with 5,000,000 cu. ft. of space to heat in manufacturing and business blocks, and secure the running of several engines in the same buildings. They supply the steam from their stations in underground pipe and power by wire. They could not get the power without doing the heating. We think you will find this a fertile field for investigation.

Citations of events in 1893 and 1894 are made advisedly as having a bearing on the development of the art. It was found that while a business could be built up along these lines that there was a great deal to do in developing heating appliances to make them sturdy and effective, and that it would be necessary to choose the industrial isolated plant as a more immediate field for both heat engineering and appliance development.

Careful study of the question of multipotential heat supply, from both engineering and business standpoints, can hardly fail to give the utmost confidence that results of the greatest value can be obtained along this line. A total fuel efficiency exceeding 35% for both low- and high-temperature heating is certainly attainable, and probably a still higher efficiency may be secured from operations on a large scale. It is in this direction that we must look for the best immediate results of electric heating in domestic life. Electrical engineers realize that the ordinary light and power station is wasteful as a heat generator and distributor, and one of the ways to improve these conditions is to introduce a basis of supply in which the load-factor is a larger percentage of the station capacity and in which low-temperature steam distribution may also be utilized. This study deserves the greatest possible care and while data are occasionally available there is still much to be learned.

In the modern apartment house we find it possible to effect a comparatively high distributive heat efficiency. The rooms are heated by low-pressure steam or hot-water radiation and the hot water for laundry, bath-room, and cooking purposes is also supplied.

Electric lighting is available, but low heat efficiency is found in cooking except in cases where gas is available. No one can question the value of gas as a fuel in cooking; we may however take the ground that when a boiler plant is required for room and water heating, and the electric plant for lighting, the use of gas in cooking is unnecessary and comparatively expensive, for it is a form of heat supply not as effectively localized as electricity and is accompanied by many disagreeable features.

In these houses electricity is already in use instead of alcohol for heating conveniences, also for heating sad-irons for laundry work and pressing; and it appears to be a question of time only when electric ovens and other cooking utensils will replace the range or the gas stove on a considerable scale. The apartment house supplied with its own boiler and electric lighting plant, approaches more closely the proper conditions for electric heating than any other mode of domestic life, as all the conditions essential to economical working are already present.

The foregoing deductions have been introduced to indicate broadly wherein the true economical basis of electric heating lies. Like all general considerations they are qualitative rather than quantitative in character. We find in industrial and commercial practice a great number of heat applications, either at high or moderate temperatures, in which close regulation and facility of control are necessary and where electric heating on some scale is applicable.

The introduction of electric lights and motors has brought into use in central stations and isolated plants a vast amount of electrical generating apparatus, so that at the outset our problem is largely one of applying electric heating apparatus on circuits already established, primarily for other purposes. On these circuits we are usually able to supply apparatus to do the work required better than it is at present accomplished. First cost and cost of operation are not the sole considerations in any apparatus; in addition to the cost, the collateral advantages derived from its use must be considered.

In domestic work there have been large numbers of household conveniences sold, notably electric sad-irons. Perhaps novelty was in many cases the reason for first purchase and use, but once used the value of the method of heating is well appreciated and extensions are made to more and different work. In this slow and conservative way electric heating in households is progressing, and there are indications of a more rapid general reception and use.

There are some installations in which all or nearly all the cooking is done by electricity. These are generally successful and economical, according to the degree to which extensive water heating is eliminated. Laundry and pressing irons are found almost uniformly satisfactory. Some of the devices used in the dining-room are counted great conveniences when electrically heated. When it comes to the kitchen the same feeling of cleanliness and refinement of methods as for the dining room is expressed and hoped for, but the housewife is not so intimately in contact with the apparatus and ignorant manipulation is encountered, which, however, generally does no other harm than to add to the expense of running. But fortunately the manipulation and control of the devices is so simple and saves the servant so much work that an honest effort is usually evidenced to use it economically.

In industrial work the progress of electric heating has been more rapid than in domestic applications, with the exception of the electric sad-iron. There are cases where heating by electricity is found cheaper than by fuels, setting aside all collateral advantages. In electric cars the more equable distribution of heat; on a satisfactory basis of effective warming is sufficient to employ the method and apparatus even at considerably greater cost than former methods of heating.

We have before us for the future two methods for the distribution of heat; the first, a multipotential heat system in which steam and electricity simultaneously are the means of transmission; secondly, a constant-potential heat system in which electricity is employed as an agent for diffused heat work in large volume, and the heat of resistance, either directly or with the additional heat of combustion of carbon, is used for high temperature purposes. The first is a combination of well known engineering practices and represents elements in successful use at the present time.

The second method is more difficult, as it includes new methods of applications and untried apparatus. For the present we have to approximate the probable final conditions by using materials at hand so far as they will go with reasonable economy, using every energy to broaden the general conception of the help and convenience arising from central station heat supply.

It has been thus far assumed that the development of electric heating depends solely upon engineering conditions without reference to the state of the art of the appliances themselves. Unfortunately the lack of sturdy resistances of high rates of heat impartivity has materially retarded commercial progress. Factors of safety have been too low and rates of working too slow. We are still without a satisfactory heat insulation and in practically the same position as the electrical industries prior to the use of mica.

A circular gas burner will impart heat at a rate equivalent to 35 watts per superficial sq. in. Electric stoves made for 110 volts will work about one-third this rate. This is a serious hindrance to electric cooking and high temperature applications. Far better apparatus could be made for lower voltages, and in this respect the state of the art closely resembles the situation of tungsten and tantalum lamps which are simply high temperature heating applications.

Since Dr. Lindeek's paper on " Material for Wire Standards of Electrical Resistance " was presented before the International Electrical Congress in Chicago in 1893, the only alloy that has been offered for resistance purposes is the nickel-chromium product; that is, in fifteen years, notwithstanding the marked development in electrical furnace work, there appears to have been but one new alloy brought out in commercial form.

Attention is called to these points to emphasize the need of further research work in materials and processes for good commercial work. The heaters on the market to-day are greatly improved over the product of fifteen years ago but there are still wide gaps to be filled. Localization of heat at high temperatures with negligible heat capacity are the prime requisites of an electric heater. Without adequate heat insulation, with resistance material of comparatively low specific resistance and high voltages in commercial practice the average design is far removed from the ideal.

DISCUSSION ON "ELECTRIC HEATING." NEW YORK, NOVEMBER 8, 1908

(Subject to final revision for the Transactions.)

Charles E. Waddell (by letter): Dividing heat applications into low-potential quantity and high-potential intensity types is a very expressive way of classifying two general conditions. In high-potential heating problems it has been demonstrated that the cost of electrical energy has little or no bearing on economy. Other factors enter that more than compensate for any discrepancy in calorific value between electricity and fuels; for example, electric glue cookers, laundry irons, and apparatus in printing and embossing plants. The field for this type of heating apparatus is decidedly small as compared with the field for low-potential applications; and it is this latter class that presents diverse conditions and offers fascinating opportunities for specific solution. Elusive in its nature, difficult to measure, and next to impossible to insulate, heat is in many respects a more subtle and difficult form of energy to control than is electricity. When comparing electric heating with fuels in the realm of domestic heating, the fact must never be lost sight of that by means of electrical measuring instruments the quantity of heat delivered by the electrical apparatus can be accurately determined; whereas in the case of fuel apparatus, while the calorific value of the fuel itself may be known, the efficiency of such apparatus is so variable and uncertain that its economy is largely a matter of conjecture.

It is doubtless true that the steam power plant by reason of its low efficiency is forever debarred from furnishing electric heat in competition with fuels. In the case of a thickly settled district, the use of exhaust steam for heating has been demonstrated as profitable and desirable; and, as Mr. Hadaway suggests, conditions may be such that it might be profitable to generate electricity for high-potential applications and use the exhaust steam for quantity work. It would appear that the scope of such a plant might be widened by applying the electric heat in districts too remote from the generating station to justify the installation of underground steam mains.

While the thermal value of a kilowatt-hour is very low (3412 B.t.u.) and electricity as a heating agent suffers by comparison with fuels, nevertheless it will not do to dismiss the whole subject as one unworthy of serious consideration. It must be remembered that the world's coal fields are being rapidly depleted, that natural gas areas are limited, and that wood as a fuel has even now virtually disappeared. Sooner or later electricity must necessarily become a factor in the field of heating. Where electricity generated from water power is obtainable, and where storage of the water through the night hours is impracticable, electrical energy for heating can be obtained at figures closely competitive with fuels. The problem in such cases becomes one of storing the energy of the water power in the form of heat, which brings up the all-important feature of heat insulation. Supplying electricity for heat as a by-product, with a view to maintaining a high load-factor on a plant, either steam or water, is a subject that will bear careful investigation in the majority of small steam and all hydroelectric plants.

In discussing boiler efficiencies, two factors are involved; first, the evaporative efficiency of the boiler; secondly, the all-day, all-season efficiency. Assuming a pound of coal has a calorific value of 14,000 B.t.u. and that under favorable conditions a given boiler plant can deliver 70 per cent to 80 per cent of this amount, the same plant in every day service seldom approximates 50 per cent of the calorific value of the fuel. As an instance of this, reference is made to the published data of a number of plants furnishing exhaust-steam heating where the annual average number of pounds of water evaporated per pound of coal is but seven and a fraction. These data are not specific as to whether they mean the evaporation is from and at 212° fahr.; and since vague in this particular, assume the heat units per pound of water to be 1000, the delivered efficiency of the fuel is then seen to be but 7000 B.t.u. Here are cases where ostensibly the most expert supervision and attendance is provided; where the system is in a measure automatic; where the connected load in radiation is many times the capacity of the plant, hence a presumably high load-factor; and, finally, the demands are diverse, all tending to uniformity in load and consequent economy in fuel. If seven pounds of water is the best average result of large systems, the probable performance of the heating apparatus in an ordinary residence or apartment house is doubtless at an efficiency that is but a small fraction of the theoretical calorific value of the fuel.

Another point that I have had impressed upon me is that not only the quantity but the intensity of heat in domestic applications is essential to success. Formerly I attributed the asserted inferiority of the large, low-temperature electric radiator as compared with a small open fire to the idiosyncrasy or psychical peculiarity of the individual rather than to any physical difference. More recently I have revised my views, and I have found that in many instances a smaller quantity of heat with which was blended an even smaller quantity of high temperature radiation is extremely grateful. If electric heating is to be introduced upon a large scale into house warming, it will be necessary to accord the art of heating and ventilating more scientific attention than is now usually bestowed upon this class of work. Unquestionably, of the quantity of heat annually radiated in domestic installations the greater portion is wasted. Since the thermal value of a kilowatt-hour is fixed and not possible to increase, the general installation of this method of heating will be accompanied by economies in application.

The power engineer burns a pound of coal in a manner that will extract the greatest number of heat units in the shortest possible time. The heating engineer, while desiring the maximum number of heat units, endeavors to prolong the time as much as possible. As electrical heating apparatus is capable of delivering a uniform heat through any duration of time and at a maximum efficiency, it possesses an advantage that makes for economy.

The argument that heat obtained from electricity equivalent to that obtained from fuels is so high in cost as to be practically debarred from general use is scarcely logical in view of modern experience. The incandescent light, for instance, though more costly than either candles or kerosene lamps, has in a large measure supplanted both.

Finally, there is one other class of quantity work to which attention has not been directed and on which some remarks may be pertinent. In drying materials on a large scale—lumber, cotton yarn, etc., the heat that is supplied is merely a means artificially to accelerate a natural process. With a moderate amount of heat applied where needed and a skilful use of air currents, an apparatus more efficient than ponderous steam apparatus appears possible.

W. N. Ryerson (by letter): Mr. Hadaway has pointed out the limitations in the use of electricity for maintaining an equable temperature in buildings during the season of cold weather, and at the present time his remarks are undoubtedly to the point. There are instances, however, in which comparison between the use of electricity and other heating agents on the basis of cost leads to erroneous conclusions. An instance in point is the office building of the Ontario Power Company at Niagara Falls which was equipped, under the plans of the architects, with a low-pressure steam heating system, having an auxiliary hot-air system with forced draught; the idea being to maintain a pressure in all of the outside rooms sufficient to prevent cold air coming through the cracks in the widnow frames, etc. The air in this auxiliary system was intended to be heated by a steam coil in the discharge of the circulating fan. Before this sytem was put in use, the writer designed an electric heater to take the place of the steam coils, and after having been in use for the last two winters it has been found that the low-pressure steam system is entirely unnecessary, a comfortable temperature being maintained in the coldest weather by the electrically heated hot air. It is true that the steam heating system in this building is a part of a much more extensive one installed throughout the transformer building, of which the office forms an L, but it is not necessary to maintain a high temperature throughout the remainder of the building, with the exception of the switchboard room which is heated by direct electric radiators. During the last winter it was found that the use of the boiler was only necessary for 25 days, and that during the remainder of the time the electric heaters in the office building and switchboard room were sufficient for all purposes.

The cost of this heater was $388.00 and it consumes 85 kw. (including power necessary for fan motor). In a plant of this size the cost of this amount of energy is negligible, whereas the natural gas and wages of boiler attendants form very real quantities. This heater supplies 72,000 cu. ft. of air space in a building exposed on three sides.

For the present and until some material capable of delivering heat at a higher rate than any resistive metal now known is found, the principal application of electricity will be in articles where the heating must be closely confined. The superiority of these articles is well recognized.

W. S. Andrews: It was my privilege to be associated with Mr. Edison while he was developing his low-tension, multiple-arc system of electrical distribution in the early 80's of the last century. I remember a statement that he made in 1881, to the effect that he expected to utilize the general distribution of low-potential electrical energy not only for public and private lighting purposes, but also for operating electrical motors to drive the machinery in mills and factories, and for electric traction; furthermore, he confidently expected to make electricity generally serviceable for the cooking of food, and, to a limited extent, for the warming of dwellings.

We all know that Mr. Edison's prediction in regard to the use of electricity for lighting purposes was very quickly realized, and also that not many years thereafter the electric motor was developed to a considerable degree of perfection, and largely used. Heating and cooking by electricity, however, has failed to show a similar advancement, and a brief discussion regarding the probable causes of this delayed development may therefore be timely and profitable with the view of bettering existing conditions.

Let us consider the use of electricity for performing ordinary cooking operations. As Mr. Hadaway says, the real difficulty consists in providing a hot-water supply economically. At the price of 5 cents per kilowatt-hour, the cost of heating a gallon of water from faucet temperature to boiling at an efficiency of say 80 per cent is a little more than two cents, which to many people would be a prohibitive price, especially as the same results can be accomplished with gas for very much less. Apart from the question of water heating, however, the operations of baking, broiling, frying, toasting, etc., by electricity can be accomplished at a reasonable expense, when electricity is sold at the rate of 5 cents per kilowatt-hour, according to my own personal experience, taking into due consideration, as Mr Hadaway. points out, the collateral advantage of being able to raise utensils to a high temperature with localized heat, thus keeping the kitchen much cooler in hot weather than is possible when using a coal or gas range. For several years past I have used electricity for cooking purposes in my home during the summer months. Water only was heated by a gas arrangement attached to the kitchen boiler, but all other heating and cooking was done by electricity at an average cost of $4.50 per month. I estimate that the average cost of heating water by gas amounted to about $1.50 per month, making an average total expense of $6.00 per month for cooking three meals per day for a family of four. This outlay also included the heating of water for laundry work and the use of an electric iron, so I do not think it can be considered as extravagant. My experience shows that an ordinary breakfast, including cereal, coffee, toast, and broiled meat, sufficient for two or three people can be cooked by electricity with an expenditure of about one kilowatt-hour, the various devices averaging as follows, on a liberal basis:

Cereal cooker	600	watts	for	20	min.	=	12,000	watt-minutes.
Coffee percolator	600	"	"	20	"	=	12,000	"
Bread toaster	600	"	"	10	"	=	6,000	"
Meat broiler	1500	"	"	20	"	=	30,000	"
							60,000	"

Or one kilowatt-hour at a cost of 5 cents.

These instances show that good service can be rendered at a reasonable expense by existing devices, but I quite agree with Mr. Hadaway in his statement that we are still far removed from ideal conditions.

In a recent lecture on this subject Dr. Steinmetz went to the root of the whole matter, in discussing the possibilities of greatly reducing the cost of electricity by improving the station load-factor, aiming to get a steady and uniform load throughout the 24 hours of the day, when he said:

> When we have accomplished that, electric power will be much cheaper than anything else and then the end will come for gas and kerosene. And that time *will* come some time and we will probably see it.

Mr. Hadaway cites some favorable cases, such as first-class apartment houses in large cities, where steam heat, hot water, and electricity are supplied to tenants, and where, therefore, electric cooking may be performed economically provided only that the price of electricity is reasonable. It is nevertheless generally true that the cost of heating water by electricity for domestic purposes, at ordinary rates for current, presents an almost insuperable obstacle to its common use, excepting in a small way, such as for hot water urns, coffee percolators, and similar table devices.

I believe with Mr. Hadaway that the field of industrial application will eventually be found equally if not more extensive and profitable than the domestic side. There are thousands of operations where heat is now applied to various parts of machines in a cumbersome and unhandy way by steam and gas where electric heat would be not only more cleanly and hygenic, but also more economical in the long run, on account of the especially favorable feature of being able to localize the heat where it is required, and other considerations covered by a variety of special conditions.

In regard to the heating of air in buildings, Mr. Hadaway has shown in a general way that the present cost of electricity when supplied from large generating stations makes extended applications prohibitively expensive. In a few special and isolated places it is applicable, also for emergency cases where a maintenance or rise of temperature may be the means of saving valuable property, as in conservatories and greenhouses, the value of these appliances is very evident.

H. P. Ball: The feature of the electric heating subject with which I am most interested is the design of the apparatus. Mr. Hadaway gives some comparative figures, stating that a circular gas burner will impart heat at a rate equivalent to 35 watts per superficial square inch, and electric heaters about one third of this amount, or about 12 watts to the square inch. He does not say how this gas burner was measured, but it might have been an annular surface, the surface of the flame, or the area of a circular disc; in any event, my experience would indicate that this rate can be exceeded. It is perfectly feasible by using modern materials, such as the new nickel-chromium metal and infusible insulating materials, to operate with watts running up as high as 20 on open stoves, and as high as 25 or even 30 on stoves which are used in connection with percolators or water heaters.

It appears that high temperature is the immediate field for electric heating devices, with the wide distribution of heat as something for the future, perhaps, but to-day the business to be had is in sad-irons and other devices where the heat is concentrated in small areas.

I call attention, therefore, to the absolute necessity of getting away from easily fusible materials, and adhering to the use of very high melting resistances mica as the insulator, on account of its extreme thinness and high ground test, standing from 1000 to 1500 volts per mil of thickness, and metals, such as aluminum-bronze, which will not readily oxidize in the air at high temperatures.

As to the problem of heating rooms, the ideal arrangement would be the use of an exposed resistance conductor in the form of a thin but wide band, so as to have a maximum radiating surface, causing the conductor to operate at the lowest temperature; for it is a well known fact that if a conductor is surrounded with insulating material the conductor will run at a higher temperature for the same dissipation than if it were exposed in the open air.

In a sad-iron or water heater it is necessary to enclose the resistance, and in doing this it must be supplied with a maximum surface by using flat ribbon resistances, and a material with a minimum thickness be used, such as mica, in order to get the heat out of the conductor into the thing we are trying to heat with the least possible thermal drop.

In a sad-iron the unit can be run at a very high current density on account of the specific capacity for heat of the surrounding iron; but in the water heater must be restricted to lower densities, and care must be exercised to see that the surrounding material is a minimum thickness, in order that the electrical energy and time taken in raising the temperature of the device up to its working temperature is the least possible.

Max Loewenthal: The author discusses the relative efficiency of steam, gas, and electricity and arrives at the almost self-evident conclusion that electrically generated heat is not so efficient for ordinary domestic or industrial operations as steam. He furthermore shows that the same is true when we compare electricity with gas for heating or cooking purposes. We have, however, many figures to prove that electrically heated appliances are as efficient, and frequently more efficient, than the same appliances heated by other means.

Take, for example, the case of an oven. The efficiency of an ordinary cooking-stove using solid fuel is only about 2 per cent, 12 per cent being wasted in obtaining a glowing fire, 70 per cent going up the chimney, and 16 per cent being radiated into the room. In a gas-stove, considering that the number of heat units obtainable from the gas at a certain price is but small compared with solid fuel, the ventilating current required for the operation alone consumes at least 80 per cent of the heat units obtained by burning the gas. In the case of an electrical oven more than 90 per cent of the heat energy can be utilized; and thus, although possibly 5 to 6 per cent only of the heat energy of the fuel is present in the electrical energy, 90 per cent of this, or 4.5 per cent of the whole energy actually goes into the food. Thus the electrical oven is practically twice as economical as any other oven, whether that oven is heated by solid fuel or by gas.

Furthermore, the comparative operating cost of electric and gas cooking depends upon two conditions; the relative rates for gas and electric heat units, and the relative heat efficiencies of gas and electric apparatus. A third quantity, the effect produced by the different rates and modes of heat applications in the two classes of utensils, may effect the efficiency slightly, but the existence of this effect is not yet verified. Starting with the heat of coal, which may be fairly estimated as 12,000 B.t.u. per pound, we compute the relative efficiency of the heat conversion as follows:

Gas	Electricity
1 pound of coal produces 5 cu. ft. gas. 5 cu. ft. of gas contain 3000 B.t.u.	1 pound of coal produces 0.25 kw. hr. 0.25 kw. hr. = 853 B.t.u.
Efficiency of heat conversion is $\frac{3000}{12000} = 25$ per cent.	Efficiency of heat conversion is $\frac{853}{12000} = 7.1$ per cent.

$$\frac{\text{Efficiency electrical heat conversion}}{\text{Efficiency gas heat conversion}} = 28.4 \text{ per cent.}$$

With manufacturing processes of equal cost per pound of coal converted, it is apparent that an electric heat unit must cost nearly four times as much as a gas heat unit, but with present processes the relative rates are:

Gas	Electricity
$1.00 per 1000 cu. ft.	$0.10 per kw-hr.
1 B.t.u.0.000167 cents.	1. B.t.u. 0.00293 cents.

$$\frac{\text{Electric B.t.u. } 0.00293}{\text{Gas B.t.u. } 0.000167} = 17.5$$

It is known that the efficiency of electrical apparatus is about four times that of gas, and consequently, as the gas utensils require four times as many B.t.u., the above figure of 17.5 is reduced to 4.4. If, then, the rate for electricity is reduced to one-quarter of that assumed, or 2.5 cents per kilowatt-hour, this figure of 4.4 is changed to 1.1 and we have practically identical operating costs. This ratio has been borne out by numerous tests.

One of the most interesting figures contained in Mr. Hadaway's paper is the one relating to room heating.

> For room heating from 85 to 110 watts are practically equivalent to steam at low pressure condensed by one square foot of radiating surface, etc.

I may add that in practice we figure about 1.5 to 2 watts per cubic foot to be heated, under average conditions.

I do not believe that the heating element of the future will be altogether in the nature of a wire, a metalic paint, etc., but will probably be of a refractory character such as a carbide, or a silicate of carbon. This will stand a red heat without apparent oxidation and is mechanically stronger than anything heretofore employed.

Charles P. Steinmetz: When using electric energy in producing heat energy for heating, cooking, baking, etc., we are confronted by the enormous handicap of the inefficiency of the thermodynamic engine. As electric power at the switchboard of a station we get only from 8 to 10 per cent of the energy of the fuel burned under the steam boilers, and have lost 90 per cent or more. When converting again this electric energy into heat energy, we can get only the same very small percentage of the heat energy of the fuel that is contained in the electric energy, and this greatly handicaps the use of electric energy in those cases where large amounts of heat are required, as in water heating. Therefore we always hear electric heating engineers refer to the use of gas or hot water or steam for the cases where large amounts of heat are required, as in water heating, or house heating, and reserving the use of electric heating for those applications where the heat capacity is small, as in cooking and baking, or for intermittent use, or where the convenience and cleanliness of electric heating outweigh other considerations. We look to future improvements in the production of electric power, and to improvements in the load-factor, to bring the cost of electric power down to such values as to compete in economy even in such fields as house warming, water heating, etc.

It is this statement of the inefficiency of electric heating, due to the inefficiency of the conversion of the heat energy of fuel into electric energy, that I desire to challenge. It is true that each kilowatt-hour of electric energy contains only a definite number of units of heat energy, 850 calories, and that the heat energy produced by the conversion of the electric energy into heat can therefore never exceed 850 calories of heat energy per kilowatt-hour, or about 8 to 10 per cent of the original heat energy of the fuel. The problem of electric heating is, however, not to produce heat energy from electric energy, but to raise the temperature of the air or some other objects by increasing the quantity of heat contained in them. This does not necessarily require producing the quantity of heat; it can be done by raising an existing quantity of heat to higher temperature, or higher heat level. For instance, to fill a vessel with water, the water could be produced by burning hydrogen gas in the air, but it would be more economical to fill the vessel with water by using the energy of the burning hydrogen to pump water from some lower level into the vessel. In the latter case, of the water in the vessel only a small part is produced; most of it is taken from an otherwise unavailable supply, a lower level.

In the thermodynamic engine, we supply a quantity of heat, at higher temperatures. Of this, a small part, say 10 per cent, is converted into mechanical energy, the remaining 90 per cent given off, " rejected ", as heat at atmospheric temperature. The thermodynamic cycle, however, is reversible, and by performing it in the reverse direction, we could take the 90 per cent of heat at atmospheric temperature; that is, from the air, or the water supply, and by the conversion of the 10 per cent of mechanical energy into heat in the reversed cycle raise the other 90 per cent of heat from atmospheric to the higher temperature, and thus supply again the 100 per cent of heat at the same theoretical temperature at which they were supplied to the thermodynamic engine in the direct cycle. In this case we would supply at the higher temperature 10 times as much heat as corresponds to the consumed electric energy; but this heat is not produced from electric energy, 90 per cent has merely been raised from a lower level, lower temperature, to a higher temperature. It is thus possible to supply, at the moderate temperature rise required by electric heating devices, many times more heat than the calories of heat energy corresponding to the consumed electric power, a larger quantity of heat even than the total number of units of heat energy of the fuel consumed in producing the electric energy, without infringing the law of conservation of energy. It is this possibility which Lord Kelvin referred to in the statement quoted in Mr. Hadaway's paper.

With a relatively moderate expenditure of electric power, such a thermodynamic engine could be operated between two temperatures, one above and one below atmospheric, and thus used to heat the houses in winter or cool them in summer. Air, taken at atmospheric temperature, is heated by adiabatic compression; its heat is abstracted; then the air is expanded and thus cooled below atmospheric temperature, and heat supplied to it until atmospheric temperature is restored. Thus between compression and expansion, heat is given off above atmospheric temperature; and between expansion and compression heat is taken in below atmospheric temperature; that is, cold given off, and as the work done by the expansion supplies most of the work of compression, electric power has to supply only the differences; that is, a part of the energy representing the heating or cooling effect. Obviously, in summer the higher temperature, in winter the lower temperature, would be rejected by exhausting into the air and taking in a fresh volume of air at atmospheric temperature. Such a thermodynamic heating apparatus should be able even with the present cost of electric power to make the cost of electric heating comparable with that of direct heating by fuel.

Townsend Wolcott (by letter): In discussing Mr. Hadaway's paper, Dr. Steinmetz makes some statements about thermodynamics which, whatever he may have meant to say, are, as he has actually made them, misleading. First, assuming a thermodynamic engine with an efficiency of 10 per cent, as he does, the first great loss of temperature fall, and consequent dissipation of energy, is between the temperature of the fire and that of the boiler, if the apparatus be a steam engine; or between the temperature of combustion and the maximum allowable temperature of the cylinder, if it be a gas engine. In the steam engine, the temperature of the fire is at least 1000° fahr., while that of the boiler is less than 400°. It is not true, therefore, that, by reversing the cycle, the original temperature can be restored to the whole amount of heat, even theoretically; for the fall from fire to boiler temperature is a completely non-reversible process, and entirely outside of the reversible cyclic process. To be sure, if we were able to work down to absolute zero, all the energy of heat of any finite temperature would be available, and the drop between fire and boiler would be of no consequence; but, with a finite lower limit of temperature, such as Mr. Steinmetz uses, this drop is of the greatest importance. Secondly, if the expansion be carried below atmospheric temperature, as Mr. Steinmetz says it is, efficiency is sacrificed; it is precisely because the expansion is isothermal at atmospheric temperature, in the apparatus described by Lord Kelvin, that the efficiency is high.

Mr. Hadaway's quotations from Lord Kelvin's paper of more than half a century ago may be a little startling to those who are not familiar with thermodynamics; first, on account of a doubt as to whether the statements therein contained are quite true, in view of the fact that, upon superficial examination, there appears to be a regeneration of dissipated energy; secondly, because, if true, the principal does not appear to have been fully utilized. Upon investigation, however, all doubts are dispelled and the whole subject is illuminated. I have not seen the mathematical investigation published with the original paper, and to which Lord Kelvin refers in the passage quoted by Mr. Hadaway; but, as the numerical statements contained in the passage check satisfactorily, even when using the most modern values for the natural constants involved, it is, perhaps, of no great importance that I have not. Let us follow through the process described by Lord Kelvin, using, in the interest of simplicity and perspicuity, the ideal cylinder of Sadi Carnot, which is frictionless and has walls which can be made alternately perfect conductors and insulators of heat, and the ordinary pressure-volume diagram. The values of the natural constants will be taken from the fifth edition of Peabody's "Thermodynamics of the Steam Engine." First suppose that the piston be withdrawn to 0.82 of full stroke, and further suppose that, at this point, the cylinder contains exactly one pound mass of air, at the normal pressure of 2116.32 lb. per square foot, which we will designate by p_1. So far, no work has been done. Now suppose the intake valve closed and the piston drawn out to full stroke, the temperature of the air in the cylinder being maintained constant by conduction through the walls of the cylinder. At the end of the stroke, the pressure will be $0.82p_1 = 1735.382$ lb. per square foot $= p_2$. The volume at p_1 we will call v_1 and at p_2

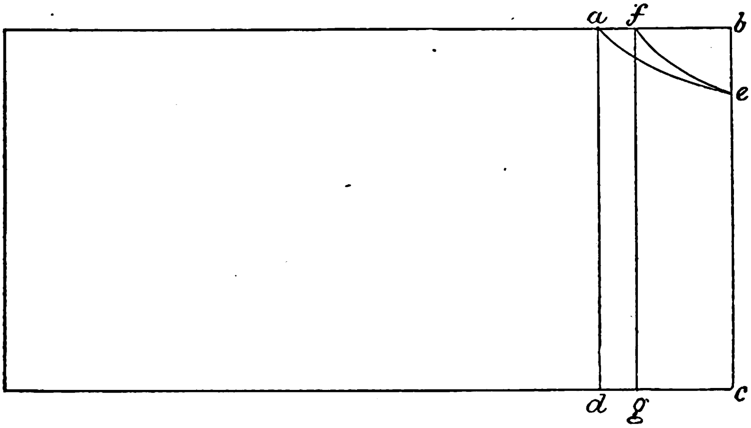

FIG. 1

we will call v_2. $v_1 = 12.84375$ cu. ft., $v_2 = 15.66311$ cu. ft. The work of isothermal expansion is

$W_i = p_1 v_1 \log_e \frac{v_2}{v_1} = 5394.186$ ft-lb., and is represented on the diagram by the area, a, e, c, d. The total work required to move the piston from p_1 to p_2 against the atmospheric pressure is $p_1 (v_2 - v_1) = 5966.668$ ft-lb., represented in the diagram by the area a, b, c, d. The difference of these areas; that is, the area, a, b, e, represents the external work supplied, $W_0 = 572.482$ ft-lb. The cylinder is now insulated and the piston allowed to go back until the pressure in the cylinder is again p_1; the volume at this point $= v_3$. The compression is adiabatic, and the temperature, of course rises. Assume the absolute zero as $-459.5°$ fahr., the specific heat of air at constant pressure as 0.2375, the mechanical equivalent of heat as 778 ft-lb. From these values we obtain that for the ratio of the specific heat of air at constant pressure to that at constant volume, $\kappa = 1.40593$. The initial temperature, $T_1 = 50°$ fahr. $= 509.5°$ absolute. The final temperature $= T_2$. From the laws of adibatic compression, $\sqrt[\kappa]{\frac{p_1}{p_2}} = \frac{v_2}{v_3} = 1.15160$, therefore, $v_3 = 13.601183$ cu. ft.; $\left(\frac{v_2}{v_3}\right)^{\kappa - 1} = 1.0589711$.

$$T_2 = \left(\frac{v_2}{v_3}\right)^{\kappa - 1} T_1 = 539.54572° \text{ absolute } = 80.04572° \text{ fahr.}$$

This checks with Lord Kelvin's figure. From these figures we have $1 - \left(\frac{v_3}{v_2}\right) = .131643$, which checks with Lord Kelvin's statement of the amount of compression. The work of adiabatic compression is $W_a = \frac{p_1 v_3}{\kappa - 1} \left(1 - \frac{T_1}{T_2}\right) = 3948.718$ ft-lb.: this is represented on the diagram by the area, f, e, c, g. The work which the atmosphere is capable of doing on the compression stroke is represented on the diagram by the area, f, b, c, g, and equals 4363.721 ft-lb. The difference between this and the work of compression = 415.003 ft-lb., and is represented on the diagram by the area, f, b, e. As this work may be, at least theoretically, stored so as to be available for use in the next expansion, it is only the difference between it and the work originally required to pull the piston out which is permanently absorbed. This difference, represented on the diagram by the area, a, f, e, equals 157.479 ft-lb. The equivalent in work of the heat required to raise one pound of air from T_1 to T_2, and at the same time expand it from v_1 to v_3; that is, to heat it at constant pressure, is 5551.698 ft-lb. As this is a little more than 35 times the work absorbed, Lord Kelvin's numerical results check completely. However, the casual reader of Lord Kelvin's paper finishes with a more or less distinct idea that some dissipated energy has been reclaimed; or, at least that the Bell-Coleman refrigerating apparatus is more economical than some others. I do not mean to intimate that Lord Kelvin had any such idea, but simply that the ordinary reader is inclined toward that opinion, and it is to make the truth regarding this matter clear that I have gone through the foregoing calculation in so much detail. The regeneration of dissipated energy, or the flow of heat from a cooler to a warmer body, without an equivalent flow of heat from a warmer to a cooler body, is contrary to the second law of thermodynamics. The number of proposed machines intended to operate in defiance of this law would probably make a respectable second to the number of proposed perpetual motion machines; but one kind does not operate any better than the other. It will be observed that the described operations do not constitute a complete cycle, as the air has not returned to its original state. Suppose we complete the cycle by allowing the air to cool off to its initial temperature and pressure, and inquire how much of the heat energy is available for conversion into work, by any imaginable device. The portion of the heat delivered at the temperature, T_2, which is available for work in a heat motor operating between the temperatures, T_1 and T_2, is $1 - \frac{T_1}{T_2}$. But, as we cannot withdraw a finite quantity of heat from the air in the cylinder without lowering its temperature, we must assume an infinite number of elementary cycles between the fixed lower temperature T_1, and the variable upper temperature, T, and integrate between the limits, T_1 and T_2. Thus, allowing for the specific heat of air.

$$\text{Available energy} = 0.2375 \int_{T_1}^{T_2} \left(1 - \frac{T_1}{T}\right) d\,T =$$

$$.2375 \left((T_2 - T_1) - T_1 \log_e \frac{T_2}{T_1}\right) = 0.2024569 \text{ B.t.u.} = 157.511 \text{ ft-lb.}$$

which is pretty accurately equal to the absorbed work, as calculated in the foregoing. Had more places of figures been employed in the calculations, the agreement would have been closer. We see from this investigation that no dissipated energy has been regenerated or recovered, and that the only energy which can be, even theoretically, recovered from the cycle is just what is put in. An examination of the records of tests of ice machines in Professor Peabody's book shows that the Bell-

Coleman apparatus is no more economical than apparatus using ammonia and other volatile liquids, but this does not in any way invalidate Mr. Hadaway's contention that the heating of houses by electric motors and Kelvin apparatus would be more economical than by rheostats, even allowing for the inevitable losses in a practical machine. If the limits of the temperature range were extended, so as to boil water or cook, the economy would diminish and, ultimately, disappear altogether.

W. S. Hadaway, Jr.: Concerning some of the criticisms of the paper; it has been my effort to make it very conservative. The logical way to look at the matter is to conserve the fuel supply so far as it can be made to go. From a business standpoint, and it is really the business standpoint that determines the engineering features, it has been shown conclusively that a demand for electric heating apparatus has been created which must be met. It has become in many ways not so much a question of what the efficiency is as of results attained.

It has been thought desirable in connection with the practical side of the problem to point out some of the difficult questions yet to be solved. I thank Dr. Steinmetz for elaborating the Kelvin method of securing heat in large quantities at low temperature.

In the construction of apparatus the one important factor which remains to be solved at present is the question of heat insulation. If we were building ships in which we had to figure a certain percentage of tonnage capacity set aside for pumps to keep the ship afloat, we would be in relatively the same position as the manufacturer of electric heating devices to-day so far as energy inputs are concerned. We have no practical method of confining heat at high temperatures.

I was asked a question as to how the statement that the gas burner corresponded to something like 35 watts per square inch was derived. That statement is based on laboratory work, in which gas stoves of ordinary construction with annular burners and with outside dimensions of approximately 6 in. are compared with an electric heater upon which a vessel of the same size was used on the two devices. It should be added, however, that the limitation of the watts per square inch is not necessarily as low as 12 watts, because on low voltages apparatus has been successfully used up to as high as 40 watts per square inch. The voltage situation, however, particularly on 220 volts, is a difficult proposition to handle, because apparatus built for that voltage has one fourth the resistance cross-section of apparatus built for 110 volts, and the electrical insulation has also to be somewhat increased.

The logical development in voltages is towards a decrease rather than an increase in the same way that the logical development of quantitative work in heating is the centralization of all the heating values at one point and the distribution of them over short distances to secure the highest fuel efficiencies in combination with the advantages which the electric heating devices give.

A paper to be presented at the 235th meeting of the American Institute of Electrical Engineers, New York, March 12, 1909.

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(*Subject to final revision for the Transactions.*)

THE INDUSTRIAL APPLICATION OF THE ELECTRIC MOTOR, AS ILLUSTRATED IN THE GARY PLANT OF THE INDIANA STEEL COMPANY*

BY B. R. SHOVER

Introduction and historical. Twenty years ago electricity, except for lighting purposes, was virtually unknown to the iron and steel industries, while to-day in all of the steel works in this country it is used as a motive power for most of the auxiliary machinery, from the ore docks to the loading beds. The electric drive is utilized in ore unloaders, ore bridges, car dumpers, bin-filling cars, scale larries, blast-furnace skips, hot-metal mixers, electric cranes of all sizes and descriptions, open-hearth charging machines, ingot buggies, gas producers, roller tables, lifting tables, transfers, hot-bed apparatus—in short, a multitude of machines too numerous to mention here. This development has been such that it would probably be no exaggeration to say that the steel industry in this country would never have reached its present proportions without the use of electric motors. As a further gauge of progress, it is significant that the larger electric manufacturing companies have been forced to establish special departments to look after the business of the steel industries.

Development of the direct-current motor. The first application of electric power to the steel-mill industry was by means of the direct-current motor. In a historical way the following remarks may be of interest, but the absolute accuracy of the dates given the author does not wish to be held entirely responsible for, though all possible care has been taken to verify them.

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* The magnitude of the work in this plant has been such that without the hearty coöperation of the staffs of all the electrical manufacturing companies (practically all of whom have contributed to the work) it would have been impossible to obtain the results above outlined. The author is, therefore, glad of this opportunity publicly to acknowledge the valuable assistance which they have given him and his company in this work.

In 1882 the first electrical installation in any steel plant in the United States was made at the works of the Edgar Thomson Steel Co., at Bessemer, Pa. It consisted of a two-light Brush arc machine.

In 1889 an electric traveling crane was installed at the works of the Pencoyd Steel Co. near Philadelphia.

In 1891 a 50 h.p., 250-volt, compound-wound generator was installed in the Edgar Thomson Steel Co. This machine was used to supply current for an experimental crane over the heating furnaces at the blooming mill.

In February, 1893, the first motor-driven roller table was put in operation at the Homestead Works of the Carnegie Steel Co.

On February 9, 1895, the first mill having all its roller tables motor-operated was started by the Ohio Steel Co., of Youngstown, Ohio.

In the early days belt-type motors, street-railway motors rewound for 250 volts were all that were available, but the severe service to which this apparatus was subjected led the manufacturers to strengthen it and to design new motors to meet the requirements; so that the steel industries both assisted in and profited by the general improvement of electrical machinery. One result of these requirements has been the development of the so-called mill motor. This motor has a heavy cast-steel frame, a large armature shaft, which can be replaced without disturbing the winding, the minimum number of bolts, ample air-gap, and fire-proof winding throughout. So successful has this type of motor proved that it is now being used almost exclusively, even on traveling cranes, regardless of the fact that the entire crane and runway must be made much heavier in order to carry the additional weight.

In order to appreciate the importance of such apparatus to the steel manufacturer it must be understood that the real efficiency of any machinery used in the industry is indicated by the amount of steel shipped per day or year. A motor of higher engineering efficiency that causes shutdowns, and consequent decrease of profit, is not nearly so efficient as a motor that operates 24 hours a day and 365 days a year, if necessary, practically without stopping. This feature is considered so important that in one plant the superintendent of the electrical department requires a special report from his mill foremen whenever the mill is delayed more than 3 minutes by changing the armature of a table motor. The steel works electrical engineer has long since recognized that the mills are built to manufacture steel, and to be successful electrical apparatus must meet the requirements, no matter how severe. To the credit of the engineers be it said that the number of absolute failures to operate any of the apparatus has been very small indeed.

Development of the alternating-current motor. The coming of the induction motor found the steel mills equipped with direct-current apparatus, but the induction motor is so much better suited for this kind of work that it has gradually worked itself into the field until to-day it forms a considerable part of the aggregate horse power used in the steel industry. The following historical notes represent the more important steps in this development.

In 1900 the Joliet works of the Illinois Steel Co. installed a 250-volt direct-current synchronous converter operating from a 2200-volt, three-phase supply, the power being furnished by an independent power company.

In 1902 the Pennsylvania Steel Co., of Harrisburg, Pa., installed an 11,000-volt transmission system.

In 1903 the first induction motor used in the steel industry was installed at the Joliet works of the Illinois Steel Co.

In June, 1904, the South works of the Illinois Steel Co. installed a synchronous converter and step-up transformer to operate a 2200-volt transmission line. and in September of the same year a 4000-kw. power plant, generating at this voltage, was installed. About the same time this voltage was stepped up to 22,000 volts for transmission to the cement works at Buffington, 12 miles away.

In December, 1904, the first installation of 6600 volts for interworks use was installed by the Lorain Steel Co. This voltage now seems to be the favorite for use in the entire steel industry, as it has been employed in many of the late installations.

The application of electric motors to the roll trains. While the United States has led in the application of electric drive to auxiliary machinery, Europe has pioneered the way in its use for driving roll trains. In the different European steel plants there are to-day about 230 motors with a normal capacity of 19,000 h.p. and a maximum capacity of 41,000 h.p. used for electric drive of non-reversing roll trains. In addition, one noteworthy installation is that of a 10,500 h.p. reversing outfit at the Hildegardehütte mine.

The first application of motors for driving roll trains in this country was made at the Edgar Thomson Steel Co., of the Carnegie Steel Co., where two three-high roll trains for rolling small rails were operated by 1500-h.p., 220-volt, direct-current motors. The speed of these motors is varied by shunt-field resistance from 100 to 125 rev. per min. The success obtained by this installation has stimulated the installation of similar outfits elsewhere.

In June, 1907, the Illinois Steel Co. put in the first and only reversing-mill drive that has been installed in this country. The mill, a 30-in. universal plate, is direct-coupled to two 2000-h.p., 150-maximum rev. per min., 575-volt, shunt-wound motors mounted on one shaft; 2200-volt, three-phase, 25-cycle, alternating-current power being used to drive a motor-generator set consisting of a 1300-h.p. motor and a 1300-kw., 600-volt, direct current generator. On the same shaft is mounted a flywheel 100 tons in weight, 13 ft. 2 in. in diameter, the whole making 375 synchronous rev. per min.

In August, 1907, at the same works, a rail mill for rolling small rails similar to those rolled at the Edgar Thomson Steel Co. was put in operation. The roll trains here, however, were driven by 2200-volt concatenated motors. The primary motor has a capacity of 1200 h.p., and runs at 120 rev. per min.; the secondary motor is 600 h.p., and runs at 82 rev. per min. In ordinary operation the resistance in the secondary motor is so adjusted that the combined speed of the two varies between 60 and 80 rev. per min. according to the character of material rolled.

The use of a storage battery. Another electrical device which has only recently been used in the steel industry is the storage battery. On March 27, 1904, the first installation of this nature was made at the Ohio works of the Carnegie Steel Co., Youngstown, Ohio. This battery had a capacity of 1600 ampere-hours and was used for regulating the load on a direct-current station. On April 29, 1905, the capacity of this battery was increased 50 per cent. The success of this installation was so marked that batteries of considerable size were installed at the Lukens

Iron & Steel Co., Coatesville, Pa. Two large batteries were also installed at the Illinois Steel Co., South Chicago, one at the Carrie furnaces of the Carnegie Steel Co., Rankin, Pa., and the largest of all at the Edgar Thomson works of the Carnegie Steel Co., Bessemer, Pa.

The use of a synchronous converter and booster regulator, with storage-battery. In 1906 an additional feature in connection with the battery was contracted for by the Ohio works. This was a combined converter and booster to be used for regulating the variable load from an alternating-current plant then being designed. This outfit, however, has not yet been put in operation.

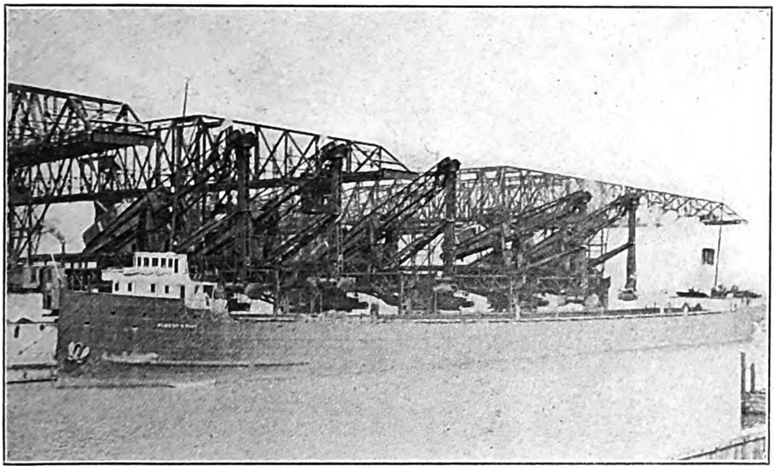


FIG. 1.—The Elbert H. Gary anchored for the first time under the unloaders.

Inception of the Gary plant. For several years the United States Steel Corporation had recognized the necessity of supplying the increased demand for its product throughout the West. To give an idea of the rapidity with which the demand for these products had grown, the total product of steel in the United States in 1894 was 4,000,000 tons, in 1895 this product had increased to 6,000,000 tons; in 1900 to 10,000,000, and in 1906 to 23,000,000 tons.

The constantly increasing proportion of this material used throughout the West necessitated the location of additional manufacturing facilities closer to the point of consumption. As none of the existing plants had ground enough on which to

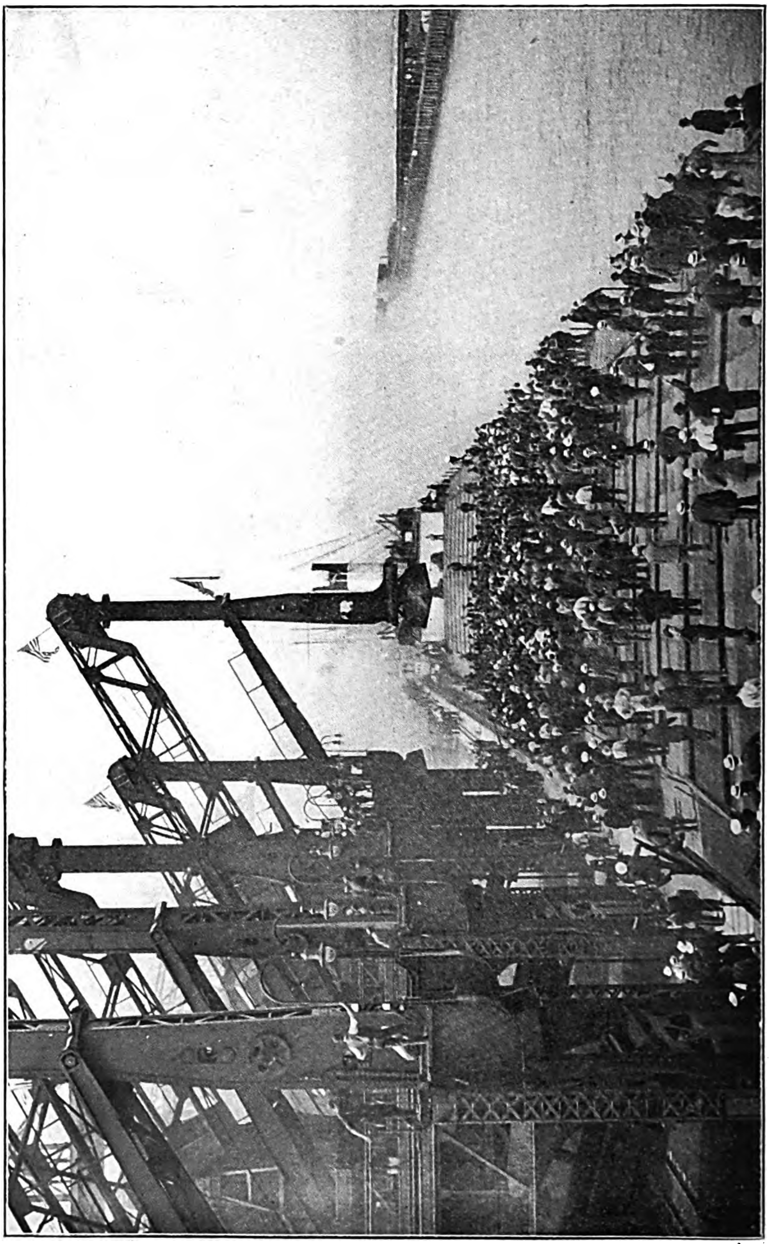


FIG. 2.—The first bucket of ore removed from the Elbert H. Gary.

instal the required increase, it was decided to build an entirely new plant, to be designed so as to embody all the features that would ensure economical production. The site chosen is at the extreme south end of Lake Michigan, about 26 miles from the center of Chicago. It consisted of about 10,000 acres of sand dunes absolutely uninhabited, and covered by a growth of scrub oak, pine, and cactus. The advantages of this location consist of lake transportation, splendid railroad facilities, and cheap land.

The governing feature in the design of the plant was economy. To this end the plant was planned so as to get the best possible transportation facilities for the material during its various stages of manufacture throughout the entire works. To add to the economy the design included the use of blast-furnace gas in gas engines, driving electric generators to furnish electric power for use wherever its application was practicable.

In the general design all features were incorporated which had proved satisfactory elsewhere, it being the intention to exploit only the new applications and schemes which were absolutely necessary to the construction of such a works and thus minimize, as far as possible, experimental apparatus.

With this object in view it was decided to abolish the use of trolley-wires for cranes, scale larries, etc. For traveling apparatus up to and including traveling cranes of 50 tons' capacity a 2-in. by ⅜-in. steel strip is used for main conductor. Apparatus of larger capacity uses a 60 lb. rail, while the unloaders and bridges have 100 lb. rails, reinforced by heavy copper cable so as to get carrying capacity sufficient to avoid excessive drop.

Layout of the plant. The layout of the plant has been so well described in several recent publications that detailed description need not be given here.

Present condition. Of the plant as planned, the slip and docks are complete; one-half of the ore yard and its machinery, including the ore bins, is finished; also one group of blast furnaces—of which three are in blast—with its complement of blowing engines and gas-washing plant, and the central pumping station. The pig-casting machines have all been in operation for some time. Four more blast furnaces, with their auxiliary buildings, are about 75 per cent completed. The No. 3 electric power station and storage-battery are ready for operation; the turbines in No. 2 power station have been in operation since July, 1908, and the remainder of the station is rapidly being completed. One-half of one open-hearth plant is in operation, a second plant is practically complete, and foundations are ready for a third. The entire shop group has been in operation for more than a year. The rail mill has been tried out. Most of the machinery has been installed in the billet mills. The foundations are laid and part of the structural material of the merchant mills is already erected.

In the part of the works now complete there are installed 110 electric traveling cranes with an aggregate lifting capacity of 3812 tons. The capacity is 22,025 h.p. in direct current and 5312 h.p. in 440-volt alternating current. 27,000 h.p. in 6600-volt alternating-current motors have already been operated. About an equal aggregate number of horse power will be required for the operation of that part of the plant now under construction, and still more for parts which are at present being designed.

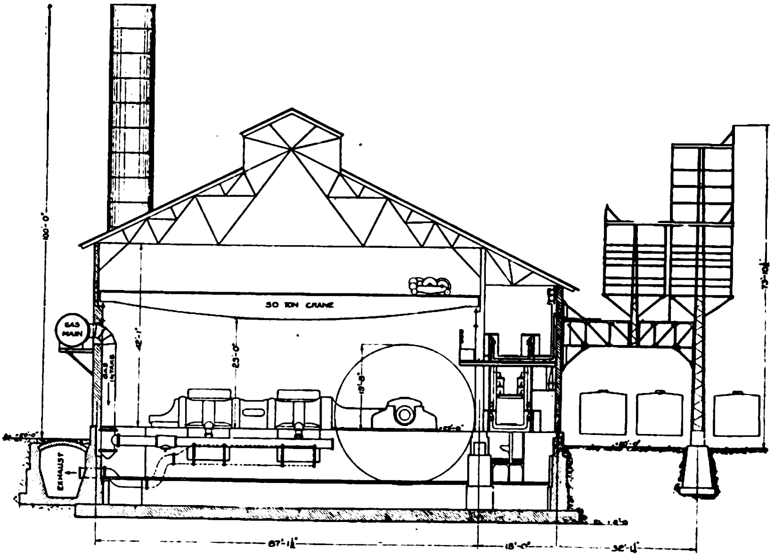
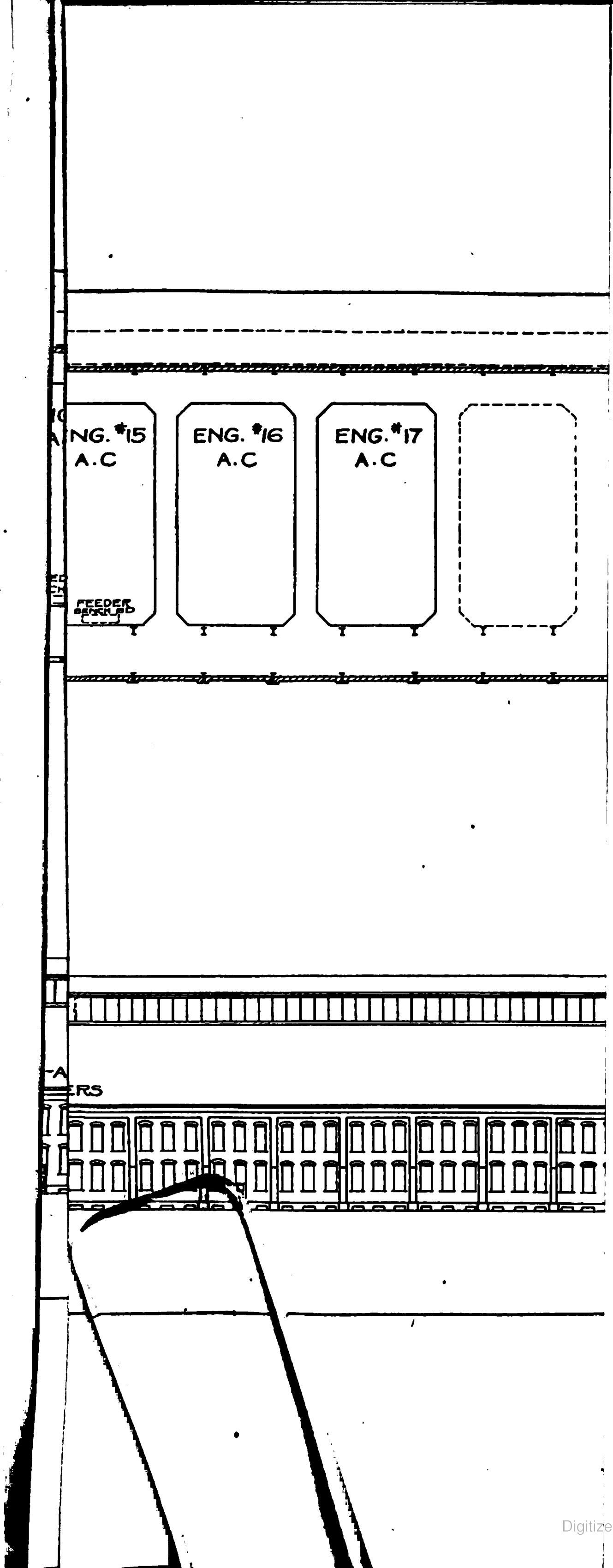


FIG. 4.—Cross-section of power station.

Electric power station. For this part of the plant it is intended to use the gas available from eight blast furnaces. On account of the large amount of current, the especially large number of circuits and units, and also to make the operation more reliable, this plant is divided into two sections, which are called power houses No. 2 and No. 3, respectively.


NG. *15
A.C
ENG. *16
A.C
ENG. *17
A.C
FEEDER
BENCH BD
RS

The eight blast furnaces producing 3600 tons of pig iron per 24 hours will give a total of 22,450,000 cu. ft. of gas per hour. Thirty per cent, or 6,750,000 cu. ft. of this gas is used for heating stoves; 7.5 per cent, or 1,700,000 cu. ft. are used under the boilers to furnish steam for spare steam engines, pumps, and miscellaneous heating; 2.5 per cent, or 600,000 cu. ft. are necessary for operating the gas washers; 12.5 per cent, or 2,800,000 cu. ft. are used by the blast-furnace blowing engines; 2.5 per cent, or 600,000 cu. ft. for auxiliary use in connection with these engines. The remaining 45 per cent, or 10,000,000 cu. ft. per hour, are available for power purposes.

If estimated at 90 B.t.u. per cubic foot and 10,000 B.t.u. per boiler horse power, this gas is equal to 110,000 boiler horse power in gas engines.

There are installed in No. 2 and No. 3 electric power stations a total of 17 gas engines each rated at 3000 h.p., but capable of about 50 per cent overload. It will therefore be seen that only approximately 50 per cent of the available power as calculated will be used in this station. This allotment will make allowance for furnaces out of blast, and for shortages of gas due to troubles that are liable to occur in furnaces during operation.

The electrical equipment of power houses No. 2 and No. 3 comprises fifteen 2000-kw. alternating-current units, two 2000-kw. direct-current units—all driven by gas engines, and also two 2000 alternating-current turbo units.

The gas engines. The gas engines are horizontal twin tandem, double-acting, running at 83⅓ rev. per min. The cylinders are 44 in. in diameter by 54 in. stroke. The floor space occupied by each engine and generator is 74 ft. by 39 ft., with total approximate weight of 1,700,000 lb. The largest piece in the engine is the bed plate, which weighs from 90 to 95 tons. The flywheel is 23 ft. in diameter and weighs 200,000 lb.

Turbines. The two turbines are rated at 2000 kw. each, and were installed primarily for use in the construction of the plant and to furnish power for starting up. It is also expected that they will assist materially in the regulation of the station by taking care, to a certain extent, of the sudden peak loads.

The switchboard contains many special features demanded by local conditions. Although its design to ensure the greatest reliability of operation necessitated the introduction of many novel features, its detailed description will be omitted here.

Storage-battery. The installation of the storage-battery was for the purpose of minimizing the fluctuation of load on the generating station. The storage-battery consists of two separate batteries of 125 cells, 73 plates per cell, each battery having a rating of 4320 amperes, with a momentary rating of from two to three times that amount. They are installed in a two-story building located directly north of the power station, the connection between the two buildings being through a tunnel.

The direct-current regulation is accomplished by means of two 2500-ampere, 35-volt boosters. The motors and generators of this booster are of the interpole type, controlled by a carbon-pile regulator acting through a motor-driven exciter. The alternating-current regulation is accomplished by means of special 2000-kw. split-pole converters. The regulating current for this converter is supplied by a series transformer in the leg of each generator lead. In turn, these transformers are connected to a totalizing transformer of the compensator type which supplies current to a synchronous motor-driven special synchronous converter. From the direct-current side of this

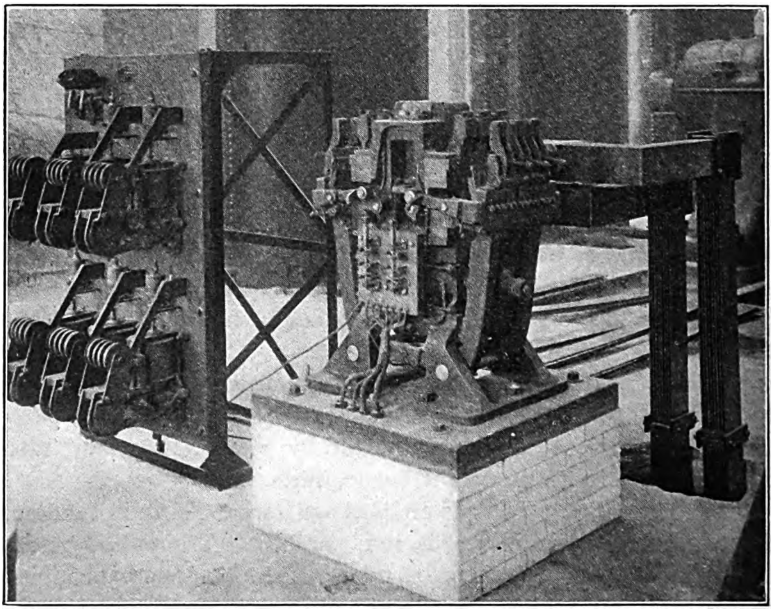


FIG. 4A 10,000-ampere remote-control switch.

converter is taken the regulating current for the split-pole converter. A special 10,000-ampere remote-control switch short-circuits the starting resistance. Fig. 4a.

The generator oil-switches are arranged so that the regulating transformer of each generator is short-circuited when that generator is not in service. Connections are also made so that when stations No. 2 and No. 3 are tied together the battery will regulate on both, but should either tie-switch be thrown out, thus disconnecting the two stations, no regulation is possible on station No. 2 and the current transformer in the legs of the generators in that station are at the same time short-circuited. In respect to the average load on the station the regulation of both direct current and alternating current is by remote control from the benchboard.

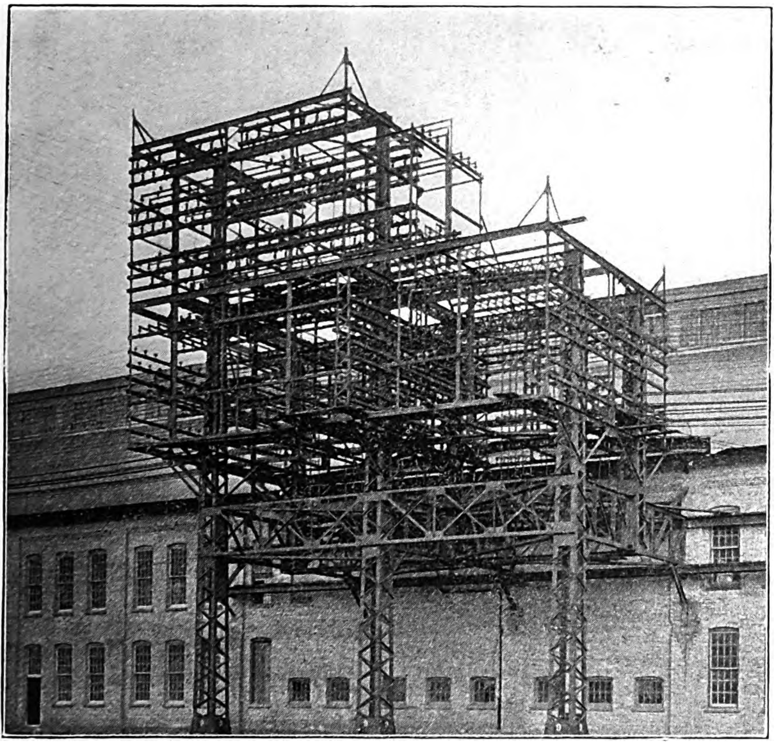


FIG. 5.—One of the special alternating-current wiring towers.

The transmission system is in duplicate; each section having sufficient capacity to carry the entire load in case of accident to the other sections. The lines are supported upon a steel tower construction made exceptionally heavy on account of the great height of the towers and heavy complement of feeders.

Sub-stations. There are three sub-stations located as shown on the plan. Sub-station No. 1 is located in the rail mill and consists of four 500-kw. motor-generator sets. These are duplicates of the exciter sets in the power station. This sub-station normally supplies current for all the direct-current apparatus in the shop group, rail mill, and billet mill.

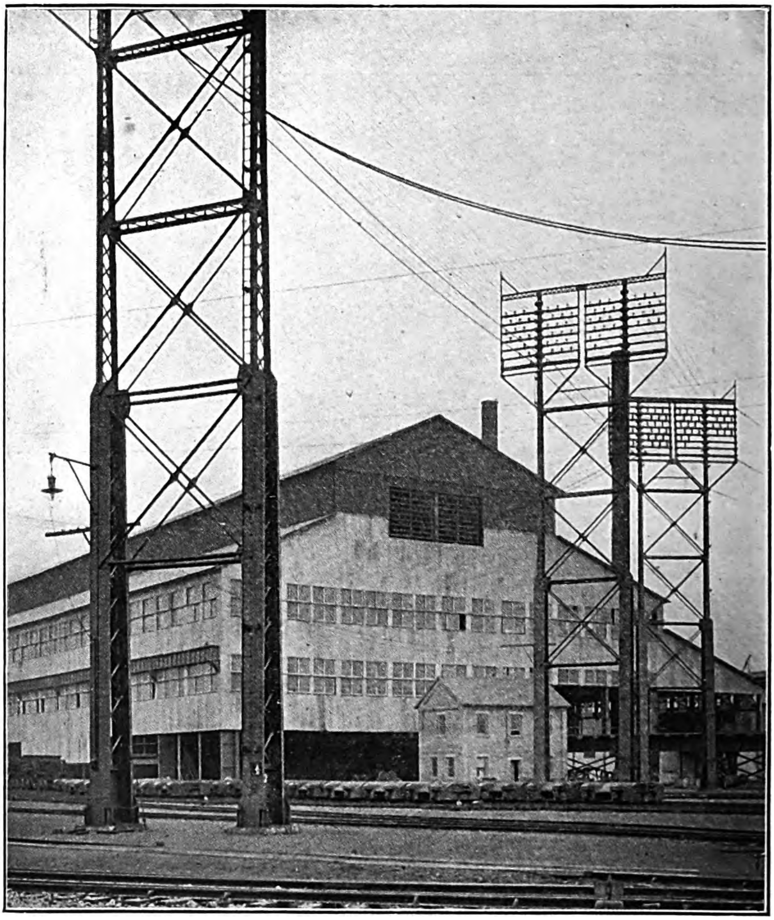


FIG. 6.—The standard 75-ft. straight-line towers.

Sub-stations No. 2 and No. 3 each have two units, duplicates of those in sub-station No. 1. They normally supply current to the ore unloaders and bridges.

The direct-current power furnished from the two 2000-kw. gas-engine driven units in the power station is used to supply the direct-current motors for the blast furnaces and open-hearth plants. When the mills are not in operation and only the lights and a few cranes are needed, it will be possible to shut down the sub-station and furnish power direct from the power

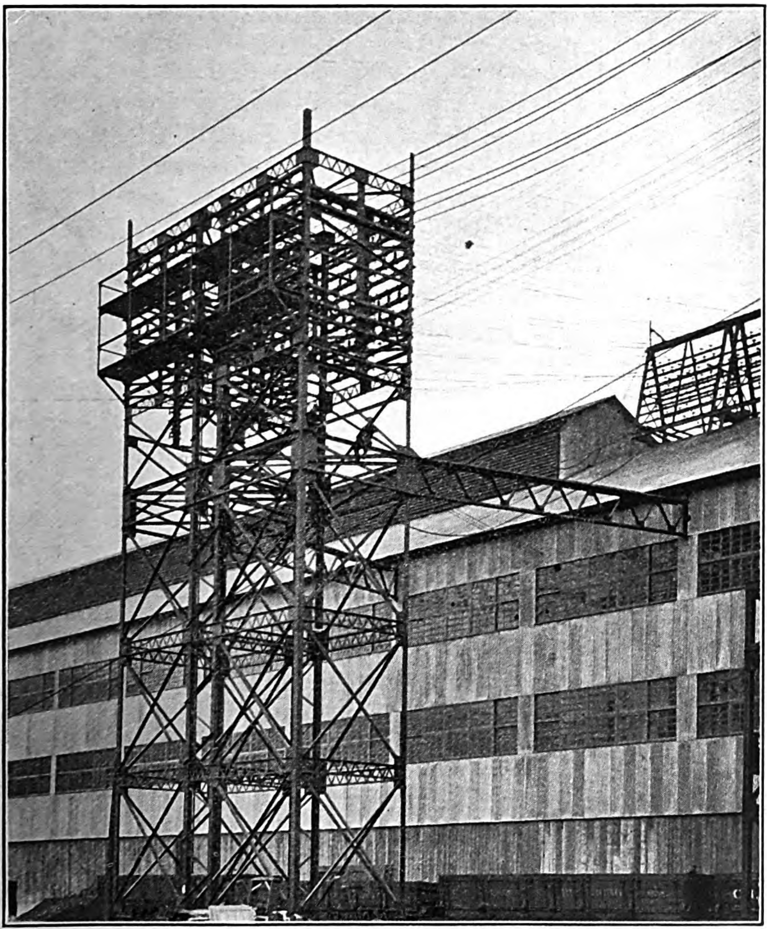


FIG. 7.—Dead-end tower between the rail and the billet mill.

station. This method of operating will result in considerable saving in operating expense.

Fig. 8 shows the character of the load on this sub-station with one machine in service. A study of this chart shows the nature of load to be such that a storage-battery installed at the sub-station would be of great advantage in its operation. This battery will probably be installed in the near future.

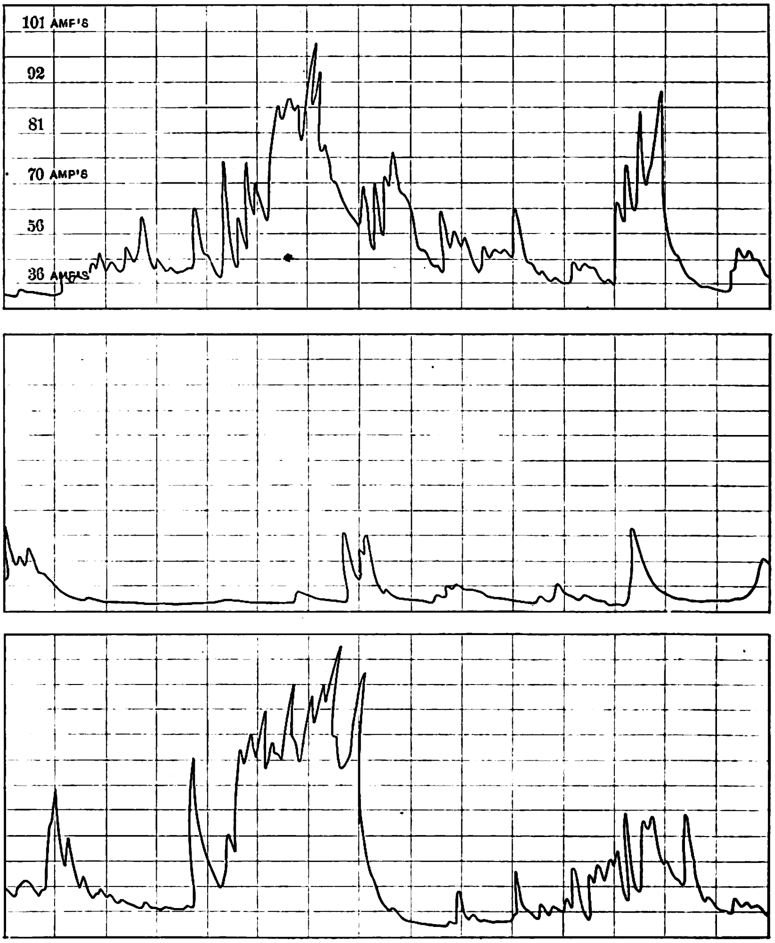


FIG. 8.—Chart showing fluctuating load on a 500 kw. sub-station motor generator set.

Transformer stations. There are located at various parts of the plant nine installations of transformers for supplying 440-

volt, three-phase alternating current. In these stations there are a total of nine 800 kilovolt-ampere, oil-insulated, water-cooled transformers, and twenty-seven 100 kilovolt-ampere, oil-insulated, self-cooling transformers.

PLANT POWER

Central pumping station. All of the water for the works is taken from the lake at one point. There are two 10-ft. tunnels running directly west from the middle of the slip, feeding a sump in the pumping station located midway between the gas-washing plants of blast furnaces 8 and 9.

At present there are installed four centrifugal pumps, each of 25,000,000 gallons capacity per 24 hours, pumping against a head of 100 ft. These pumps are driven by three-phase, 440-volt, 500-rev. per min. induction motors.

In order to make this installation as free as possible from interruptions due to electrical troubles, there are two main feeders from the station, one coming from power station No. 2, the other from power station No. 3. Each feeder has its own oil-switch feeding three 800 kilovolt-ampere transformers, and two of the motor-driven pumps are operated from each set of transformers. The bus-bars are provided with disconnecting switches so that either set or both sets of transformers can be operated from either or both main feeders.

Gas-washing plant. In the tabulation of the use of blast-furnace gas there is an allowance of 2.5 per cent for auxiliary machinery. This auxiliary machinery is used in the gas-washing plant. There is one such plant for every group of four blast furnaces. Each gas-washing plant consists of eight washers, driven by 150-h.p., 440-volt, 375 rev. per min. induction motors. These motors are fed from one of the transformer installations, but the secondaries of this transformer station can also be tied in parallel with the transformers in the pumping station, running both as a unit. In case of the failure of one of the stations, a part of the pumps and the gas washers can be operated from the other station.

Repair shops. To the south of the rail mill on both sides of the main roadway are located the various repair shops, consisting of machine shops, boiler shop, blacksmith shop, foundry, electric repair shop, carpenter and pattern shop, pattern storage, general store house, brick shed, stable, roll shop, and locomotive house. These shops are operated solely for the repairs necessary to the apparatus throughout the plant, and when in normal operation very little material is purchased from the outside in the finished state, practically all the work being done within the plant. A total motor capacity of 2440 h.p. is installed for operating these shops.

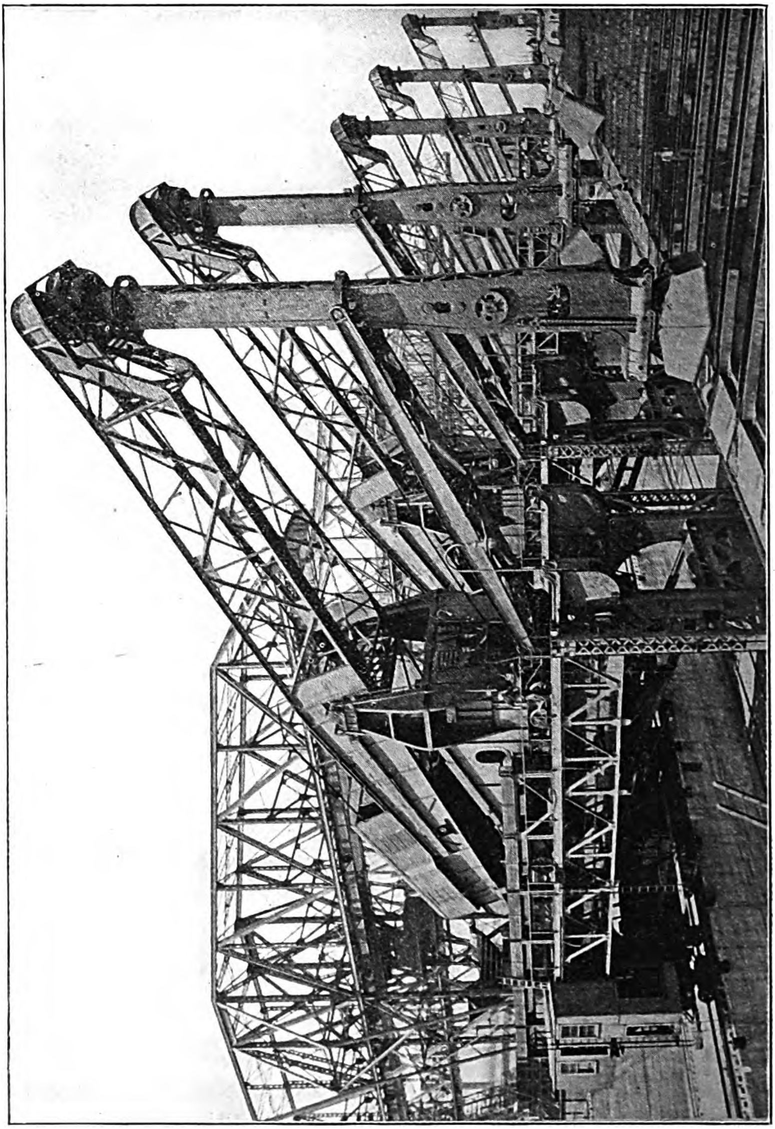


Fig. 10.—Electrically operated ore unloaders.

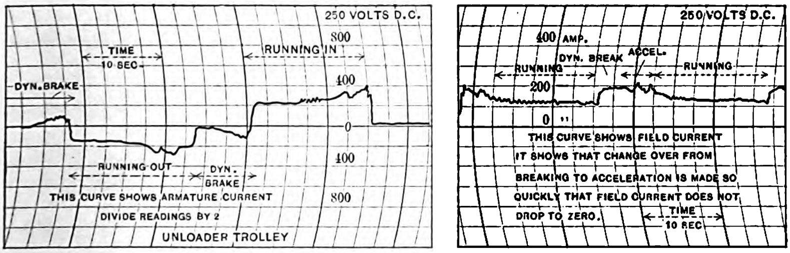
The following description is given in the same order as that in which the raw material is carried through the various processes, until it comes out as finished steel.

Ore unloaders. Located on the edge of the slip are five ore unloaders, shown in Fig. 10, of 10-tons capacity each. The total weight of each machine is 890,000 lb. The motor equipment of these unloaders is given in the following table:

TABLE A.—ORE UNLOADER

	Horse power	Total horse power	Service	Type
2	25	50	Bucket rotate ore gate	Series direct-current
1	50	50	Trolley	Series direct-current
1	85	85	Bucket close	Compound direct-current 75 per cent shunt 25 per cent series
1	100	100	Br. & Car	Series direct-current
1	150	150	Hoist	Compound direct-current 60 per cent shunt 40 per cent series
		435 total		

Total weight 890,000 lb.



FIGS. 11 and 12.—Charts showing the fluctuating load on the ore unloaders.

The character of the load due to the various motions of these machines is given in the following. Fig. 11 shows the load on the trolley motor on which is used a dynamic brake for stopping. Fig. 12 shows that the change from driving to braking is made so quickly that no record whatever is made of this interruption by the recording instrument. Fig. 13 shows very clearly the power required for hoisting and lowering. With the exception of the car haulage and bridge motion, all motions of the unloader are controlled through distant-controlled automatic magnetic torque-limit controllers. The master controllers for operating these motors are located in the leg of the unloader, so that the operator who rides with the bucket not only has a clear view of everything he is doing, but has absolute control of all motions of the machine.

Ore bridges. The ore taken out of the boats is deposited in a huge concrete trough directly in the rear of the unloaders. From this point it is picked up by the ore bridges, of which there are five. These bridges are of the cantilever type, having a total over-all length of 459 ft. The lifting capacity of this bridge is 13 tons of ore, in addition to the weight of the bucket. The total weight of the bridge is 238,000 lb. The rear end of the bridge is considerably longer than is necessary to take ore out of the trough; the bridge was made this way so as to be used as a traveling crane for repairing the unloaders.

The motor equipment of the bridges is given in the following table. The trolley and hoist motions are controlled by automatic magnetic control. The secondary motions, which are seldom used, are ordinary hand controlled. Fig. 15 represents clearly the character of load on the hoist and trolley motor of the bridge.

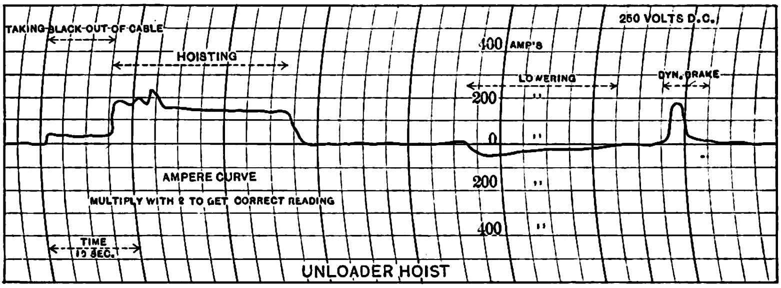


FIG. 13.—Charts showing the fluctuating load on the ore unloaders.

TABLE B.—ORE BRIDGE

	Horse power	Total horse power	Service	Type
4	30	120	Bridge	Series direct-current
4	40	160	Trolley	Series direct-current
4	80	320	Hoist	Series direct-current
1	10	10	Ore pocket	Shunt direct-current
1	8.5	8.5	Air compressor	Series direc-tcurrent
		Total h.p. 618.5		

Weight of bridge	238,000 lb.
Capacity of hopper	60,000 lb.
Total	298.000 lb.

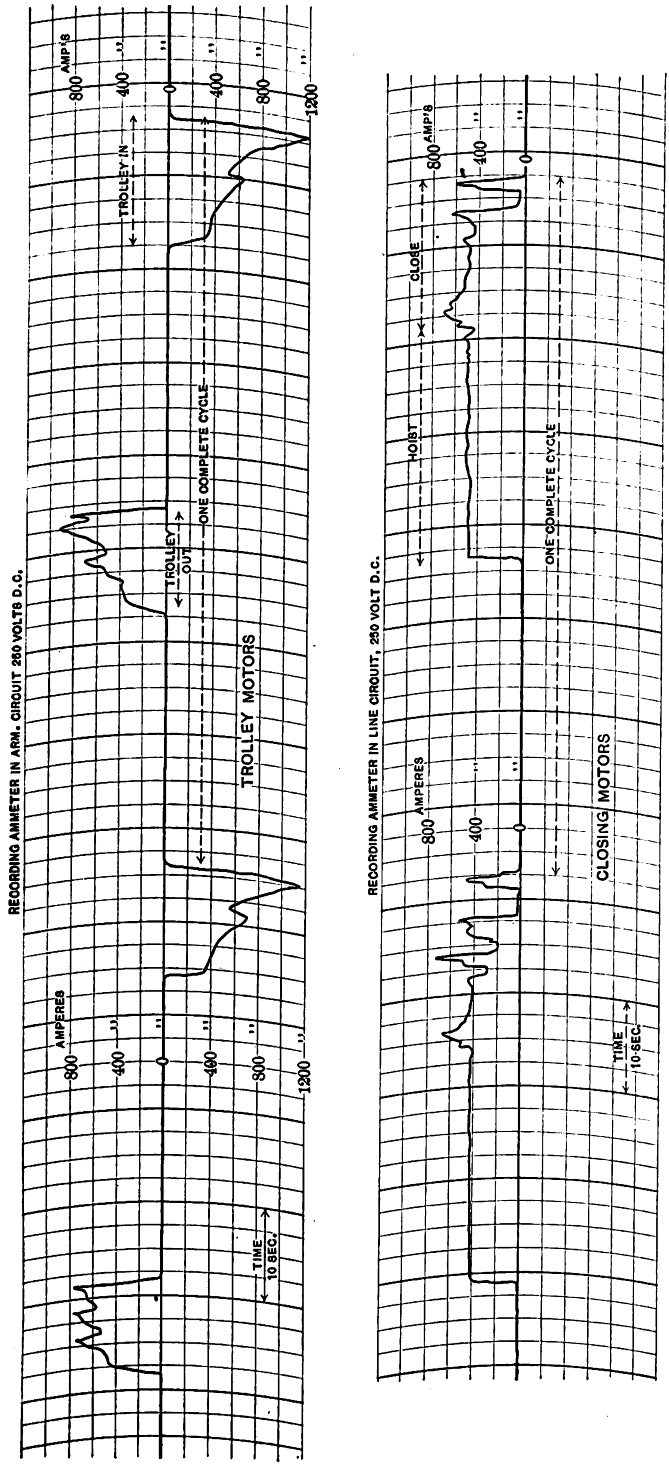


FIG. 15.—Chart showing the varying load on the ore bridges.

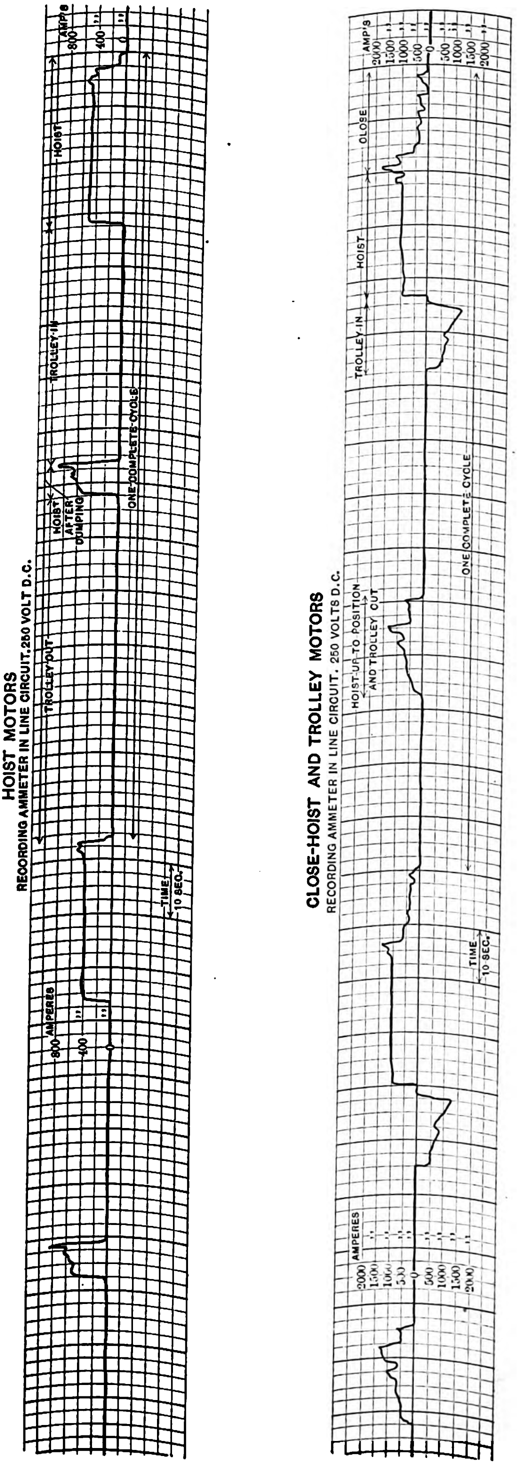


FIG. 15.—Charts showing the varying load on the ore bridges.

Bins with transfer car. Between the order yard and the line of blast furnaces there is located a long steel trestle-like structure which contains the ore. coke and limestone bins. The ore picked from stock by the bridge is deposited in a transfer car of 100,000 lb. capacity, the electrical equipment of which consists of two 50-h.p. motors operated by means of an ordinary street-car controller, and an air compresser supplying air for opening and closing the doors and for air brakes. This car is used for transferring the ore from the bridge to the appropriate bin.

Scale larries. Underneath the bins are the scale larries, driven by one 21-h.p. direct-current series motor, and carrying a similar motor for opening and closing the door of the bin. This larry is used for transforming ore, coke, and limestone from the various bins in the appropriate quantities and depositing it in the blast-furnace skip.

Skip cars. The material is carried form this stock house and dumped into the top of the furnace by means of a double skip, driven by a 150-h.p. compound-wound motor. The control of this skip is absolutely automatic; the operator simply starts it up, after which the accelerating, running, retarding, and stopping is entirely automatic.

The total travel of this skip is 163 ft. up an incline at 60 degrees to the horizontal. The time of making one trip is 60 seconds. The loads carried are approximately as follows:

Ore	7000 lb.
Coke	3600 "
Limestone	6000 "

In spite of the variable weights carried this skip stops automatically within about 4 in. of the same place under all conditions. In the cast-house of each furnace is located a 15-ton crane for handling runners, scrap, etc.

Pig-casting machine. For taking care of the material from the blast furnaces on Sundays, when the open-hearth plant is not in operation, there is provided a pig-casting machine, There is a main building in which are located two double-trolley ladle cranes; the main hoist is 75 tons, and the auxiliary hoist 15 tons. There are six strings of moulds and conveyors for disposing of the cast material. The ladle is handled by a 5-ton electrically operated jib-crane. The moulds are driven by 40-h.p., 750-rev. per min. induction motors and conveyed by 30-h.p., 750-rev. per min. induction motors.

Open hearths. Each open-hearth plant consists of fourteen 60-ton furnaces. The molten metal from the blast furnaces is poured into a 300-ton mixer by a 75-ton electric ladle crane of the same design as that in the pig-machine building.

The metal is carried from the mixer to a point in front of the various furnaces by an electrically operated hot-metal car whose equipment consists of two 25-h.p., 250-volt, 290-rev. per min. series motors, operated by a standard series-parallel controller. The ladle from this car is handled and the contents poured directly into the open-hearth furnaces by another 75-ton ladle crane.

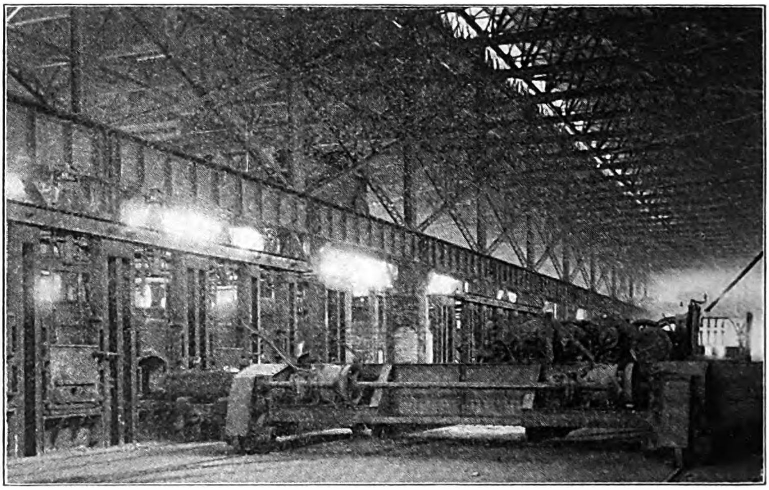


Fig. 16.—Low type open-hearth charging machine.

The cold scrap for charging the furnace is stored and handled in the stock-yard, which is entirely covered by two 5-ton electric traveling cranes. The stock is handled by means of electro-magnets, each one capable of handling from 1000 lb. to 2000 lb. of scrap, according to the character of the material, or of lifting 10,000 lb. in large pieces. After this scrap is loaded, the charging boxes are shifted in front of the open-hearth furnaces and the contents put in by means of a low-type charging machine, as shown in Fig. 16. The equipment consists of: a main hoist, with a 30-h.p. series motor; bridge travel, two 30-h.p. series motors; trolley, 20-h.p. series motor; tilting, 11-h.p. series motor; rotate, 3.25-h.p. series motor.

The steel is handled in 60-ton ladles by three 125-ton ladle cranes. The electric equipment is as follows: main hoist, 110 h.p.; first auxiliary hoist, 50 h.p.; second auxiliary hoist, 30 h.p.; main trolley, 30 h.p.; auxiliary trolley, 11 h.p.; bridge travel, two 50-h.p. motors. The controllers for this apparatus, except that for the main hoist on all ladle cranes, (which is automatic magnetic control) are of the ordinary hand-operated lever type.

The electric equipment of the coal-handling apparatus in connection with the gas producers for these furnaces consists of a coal crusher driven by a 25-h.p. direct-current motor; a double-skip coal elevator driven by a motor similar to that on the coal crusher; and four hopper cranes, each driven by 7.5-h.p. series motors. The hopper cranes are used for distributing crushed coal in overhead bins directly into the producers.

The control of the skip is entirely automatic in its action. As the descending car approaches the bottom point of its travel, it opens the door of the coal bin; in stopping it rests on a counterweighted lever. When the skip is nearly filled with coal the counterweight on this lever is overbalanced, the skip dropping down about 3 in. more. This actuates the switch which starts the skip on its upward travel, its first action being to close the door of the coal bin. The operation is repeated by the second skip and continuous unless stopped, until the coal bin is entirely empty.

As part of the open-hearth plant there are two stripper buildings One of these buildings contains one, and the other two, 200-ton electrically operated stripper cranes. These cranes are equipped with 100-h.p., 375-rev. per min. series motors on the main hoist; a duplicate to the above on the stripping hoist; 30-h.p., 500 rev. per min. trolley, and one 50-h.p. 480-rev. per min. on the bridge.

In the soaking pits are three 7.5-ton soaking-pit or ingot cranes. Each of these cranes has a 5-ton, high-speed auxiliary hoist on the trolley for repairing the pits. The electrical equipment is as follows: main hoist, 50 h.p.; auxiliary hoist, 30 h.p.; trolley, 7.5 h.p.; bridge, two 50 h.p.; tongs turning and opening, 5 h.p.

For delivering the ingots from the pit to the first table in the rolling mill two ingot buggies are used, for which a special control has been designed. Each buggy is intended to take care of six rows of four pits which are located respectively north and south of the table. To prevent the two buggies colliding, should both happen to be coming toward the table at the same time, the trolley bars through which the current is transmitted to the motors on the buggies are in three sections, one section in front of the table and one long section on each end of that. Each controller has six points corresponding to the six rows of pits, one point corresponding to the table and one to the off position. The operator can throw his controller to the point representing the row of pits to which he desires to run, and when the buggy reaches this point it is automatically stopped.

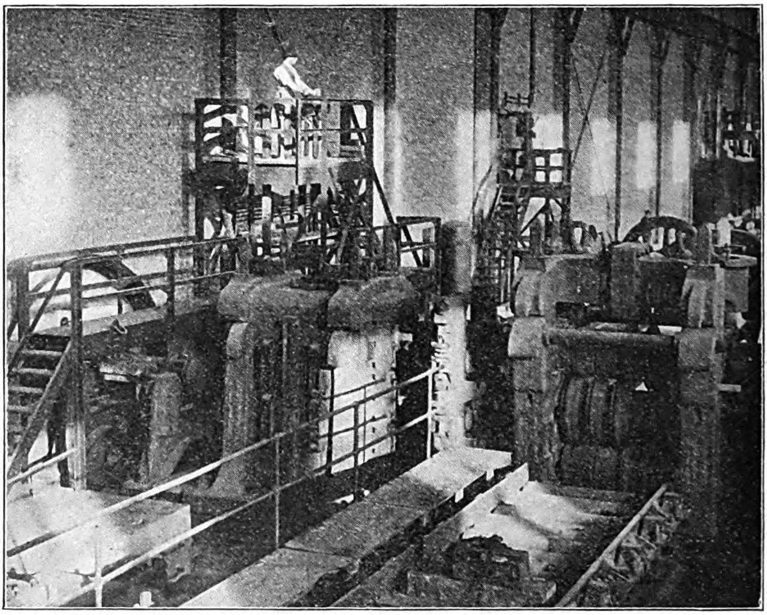


FIG. 17.—Control pulpits for rail mill

Return motion with controller on the table position will bring the buggy up to the table—where, however, on account of the great accuracy of the stop, the buggy is not stopped automatically but at the will of the operator. When one buggy is at the table it is impossible for the other one to reach that point, as the two controllers are so interlocked as to prevent this occurrence.

Table and transfer motors. In the rolling mill proper there are 21 tables and two transfers, all of which are controlled by automatic magnetic torque-limiting control.

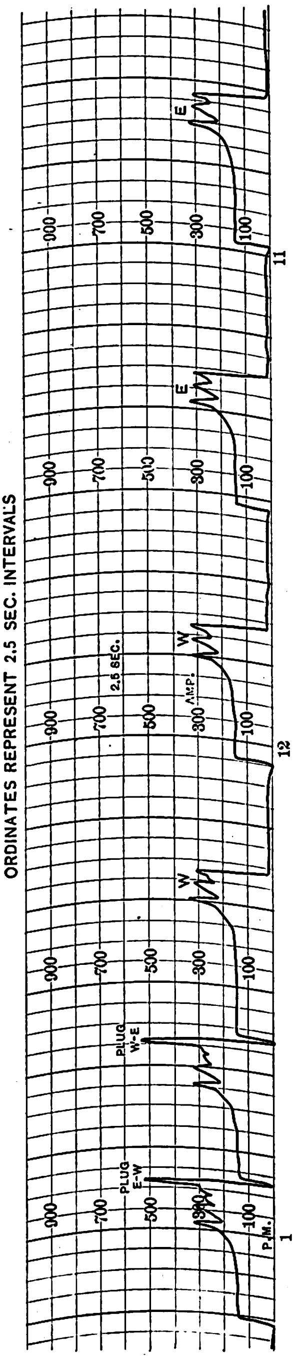


FIG. 18.—Chart showing current variation on two 25 h.p. motors operating in parallel on the same shaft, driving a mill table.

The eight operators stand on elevated platforms or pulpits, Fig. 17. Some of the controllers are mounted on the operating pulpits and others on special platforms located near the motors which they control.

These tables and transfer motors are all of the so-called mill type. Tables running constantly are equipped with series-shunt motors. Those doing considerable amount of reversing or frequent starting and stopping have series-wound motors. Fig. 18 gives the ampere chart of one of these tables.

The transfers are simple chain drive, having two sets of dogs for moving the rail sidewise, and the control is entirely automatic. When the operator throws his controller to the forward position, the transfer chain makes one-half revolution, depositing the rail in the proper place. Then the motor stops automatically.

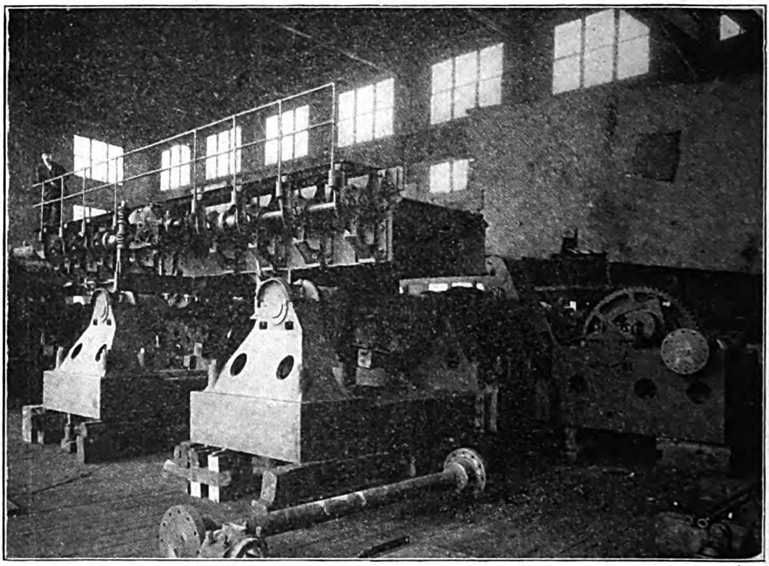


Fig. 19.—Lifting table for the 40-inch blooming mill.

The next motion, for transfering the following rail, is made by the operator putting his controller to the "off" position and again throwing it to the "on" position.

An interesting feature of the auxiliary drive is that of the lifting table at the three-high 40-in. blooming mill, Figs. 19, 20, 21. This table has a total weight of 256,000, partly counterbalanced by means of a cylinder containing air at 500 lb. per square inch pressure, and is lifted or lowered 40 in. in 3 sec. The, operating motor, is 250-h.p. 250-volt direct-current, 100-rev. per min. compound wound. The control, like that of the table motors, is entirely automatic and is manipulated by the operator simply throwing his master controller to the up or down position, the accelerating, running, retarding, and stopping being taken care of automatically.

There is also a tilting table at the three-high roughing rolls similar to the lifting table, but of considerably less weight.

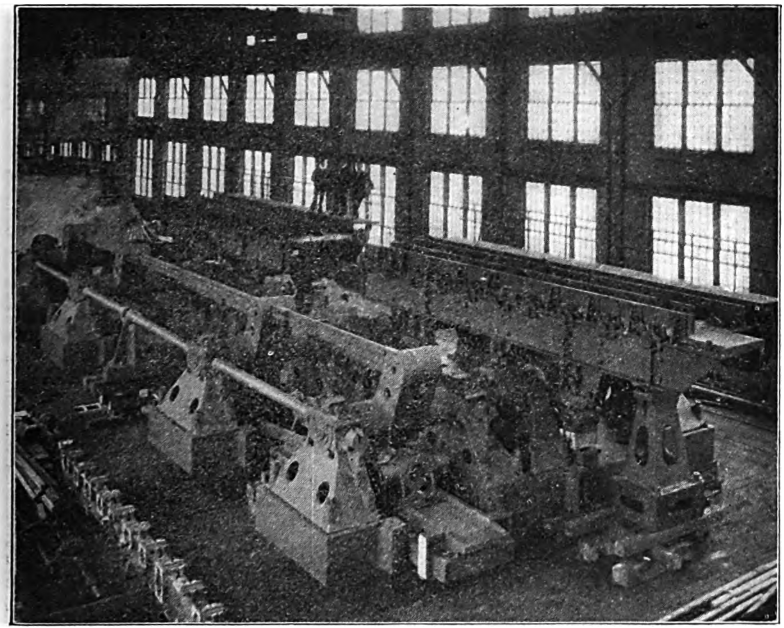


Fig. 20.—Lifting table for the 40-inch blooming mill.

This table gives one complete stroke of 26 in. either up or down in 1.5 sec. It is driven by a 150-h.p., 250-volt, 100-rev. per min., compound-wound motor and is controlled like the lifting table.

The hot saws, Fig. 23, five in number, are driven individually by 40-h.p., 750-rev. per min. induction motors. The saws are 40 in. in diameter and make 1440 rev. per min. All five are raised and lowered at one time by a crank shaft, operated by a 25-h.p. series shunt-wound mill-type motor. The control is similar to that of the lifting table, except that if the operator throws his control to the first point the saws lower and stop in that position. It is then necessary for him to bring his control to the first point on the reverse in order to raise the saws; then the latter come up to the top and again stop automatically. In regular operation, however, the operator throws to the second point; upon which the saws lower, cut the rail and again rise, stopping automatically in the upper position.

The cambering machine is driven by a 40-h.p., 750-rev. per min. induction motor. On the hot beds, four in number, there is a push-up for shoving the rails off the delivery table on to the beds, and a pull-up for dragging the rails from the beds on to the receiving table in the finishing mill. These "push-ups" and "pull-ups" are driven by 75-h.p. series mill-type motors, the controllers of which are also automatic.

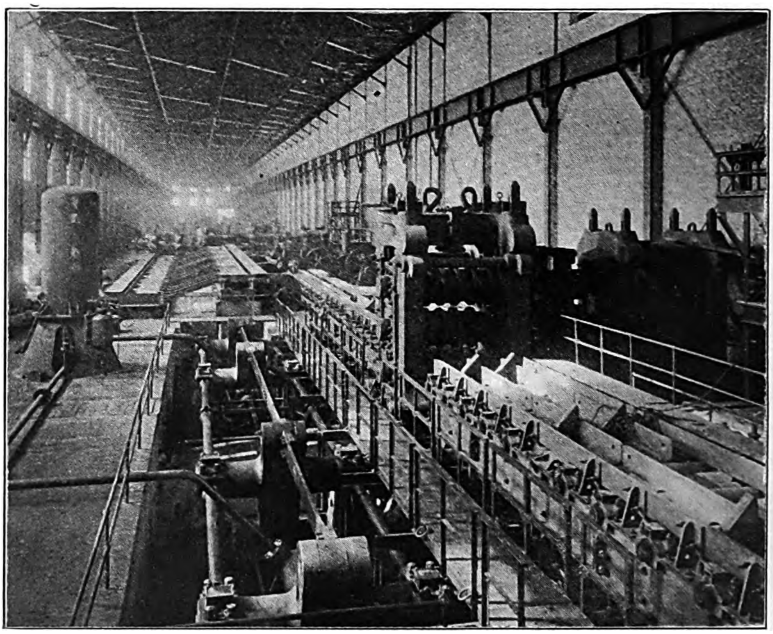


FIG. 21.—Lifting table for the-40-inch blooming mill.

From the receiving table the rails are delivered in both directions to the finishing department by feed tables similar to those in the rail mill. Because of the continuous running of these feed tables the controllers are the ordinary hand-operated type. For delivering the rails from this table to the straightening beds "kick-offs" are used. These are simply bars lying normally below the surface of the table but raised at an angle so that rails are lifted and then slid off by means of a cam on a motor-operated shaft. The straightening presses, Fig. 24 18 in number, are driven by 10-h.p., 750-rev. per min. high-resistance rotor induction motors. Opposite the ends of the straightening beds for each straightening press is located a 24-in. headlight in which is used an ordinary 16-c.p. lamp to enable the straightener to see his rail clearly.

The drill presses, 18 in number, are driven by 10-h.p., 750-rev. per min. induction motors with ordinary squirrel-cage rotors.

All of the induction motors in the finishing department are standard and are controlled by means of a triple-pole, double-throw switch which is connected to a five-wire system. The two extra wires are taps taken off the main transformers, thus furnishing low voltage for starting. This system does away entirely with the complication and trouble accompanying individual starting compensators.

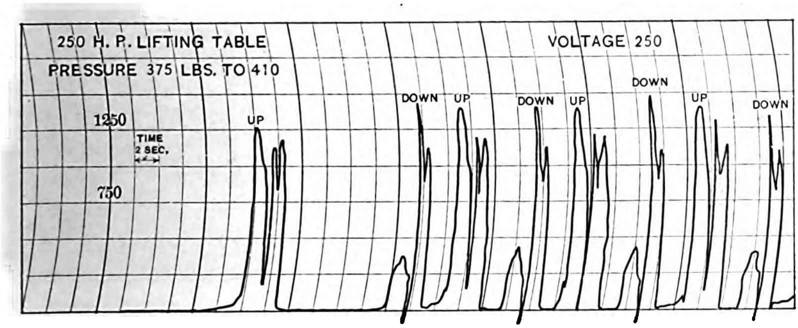


Fig. 22.—Chart showing load on lifting table.

The loading beds outside are covered by two special electric cranes which transfer the rails from one part to the other or load them in cars, the rails being handled by means of large special magnets.

On the south side of the runway of these cranes is also a small monorail crane, whose sole purpose is to deliver rails to the cold-saw bed.

The cold saw, a tooth saw 42 in. in diameter making 1800 rev. per min. is driven by a 100-h.p., 750-rev. per min. induction motor. This saw is capable of cutting an 85-lb. rail in 22 seconds, the load varying between 50 and 100 h.p. according to the part of the rail that is being cut.

Motors for driving the rolls. As outlined earlier in the paper, although electric motors have been used for some time to drive rolls, the motors used in this plant are several times larger than any motors of their type previously built. Their use for this purpose marks a new era in the industrial application of electric power, and a short description of some of the principal features in the design of these motors is not out of place.

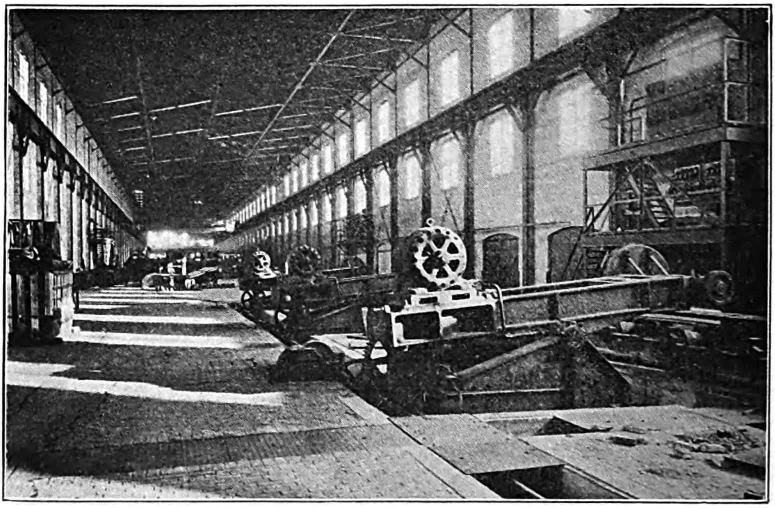


FIG. 23.—The hot saws.

The main rolls of the mill are driven by six induction motors having a combined capacity of 24,000 h.p. made up of the following units:

Two	2000 h.p. at	214	rev. per min.
One	2000 h.p. at	68	"
One	6000 h.p. at	88	"
One	6000 h.p. at	83	"
One	6000 h.p. at	75	"

In the construction of these motors the parts were made extremely heavy and rigid, following out as far as possible the practice which has proved successful in the construction of steam engines for similar duty. The stator frame is of the box-type construction, and is split into four sections for ease in handling and transportation. The rotor spider is of cast steel and is made up of four sections with two arms per section.

Horse power:					
Normal continuous rating 40° rise	2000	2000	6000	6000	6000
25% overload continuous 50° cent. rise	2500	2500	7500	7500	7500
50% overload for 1 hr. 60° cent. rise	3000	3000	9000	9000	9000
Speed:					
Synchronous	214	68	83.3	88	75
Full load					
Maximum slip, %					
Performance specification number					
Outline drawing number					
Bearings:					
FLYWHEEL SIDE.					
Diameter	24	26	30	30	30
Length	60	65	70	70	70
COLLECTOR SIDE.					
Diameter	24	26	30	30	30
Length	60	65	70	70	70
Thrust collar area	575	910	1370	1370	1370
Revolving part of motor:					
Diameter	8 ft. 8 in.	21 ft. 0 in.	21 ft. 0 in.	21 ft. 0 in.	21 ft. 0 in.
Flywheel effect, lb. at 1 ft. radius	354,000	8,950,000	11,600,000	11,600,000	14,100,000
Stationary part of motor:					
Outside diam. of frame	13 ft. 4 in.	28 ft. 0 in.	28 ft. 0 in.	28 ft. 0 in.	28 ft. 0 in.
Width of frame	3 ft. 10 in.	3 ft. 8 in.	4 ft. 11 in.	4 ft. 11 in.	4 ft. 11 in.
Air-gap, total	0.28	0.40	0.40	0.40	0.40
Induction motor:					
Poles	14	36	44	34	40
Horse power	2000	2000	6000	6000	6000
Rev. per min	214	68	83	88	75
Volts	6600	6600	6600	6600	6600
Efficiency at full load	95%	93%	95.5%	95.5%	95.5%
Power-factor at full load	89%	80%	87%	88%	88%
Break-down torque	6,800h.p.	5,100h.p.	18,500h.p.	20,600h.p.	16,400h.p.
Flywheel:					
Material	Laminated steel		—	—	—
Number of sections					
Diameter	17 ft.	—	—	—	—
Outline dimensions:					
Height of machine above bottom of base	12 ft. 2 in.	21 ft. 0 in.	21 ft. 0 in.	21 ft. 0 in.	21 ft. 0 in.
Width of bed plate	20 ft. 4 in.	32 ft. 8 in.	32 ft. 8 in.	32 ft. 8 in.	32 ft. 8 in.
Length of bed plate	20 ft. 2 in.	18ft 11½in	21 ft. 9 in.	21 ft. 9 in.	21 ft. 9 in.
Total length of shaft	22 ft.4¾in.	21 ft.3¾in.	24 ft.6¾in.	24 ft.6¾in.	24 ft.6¾in.
Center line of shaft to bottom of base.	5 ft. 6 in.	7 ft. 0 in.	7 ft. 0 in.	7 ft. 0 in.	7 ft. 0 in.
Weights:					
Stationary part of motor	42,500	126,000	175,000	175,000	175,000
Rotating part of motor without shaft	30,800	148,000	176,000	176,000	209,000
Shaft (hollow)	33,400	34,300	50,000	50,000	50,000
Pillow-blocks with bearings	72,300	105,500	138,000	138,000	138,000
Bed plate	100,000	150,000	185,500	185,500	185.500
Flywheel	100,000	—	—	—	—
TOTAL.					
Without flywheel	296,000	—	—	—	—
Complete	396,000	578,000	749,000	749,000	783,000

FIG. 25

The sections are bolted to disc hubs which are pressed on the shaft.

As the flywheel effect of the rotors necessary to overcome the excessive loads in rolling can only be determined accurately by actual trial, it was deemed advisable where possible to construct the motors so that the flywheel effect could be altered after the motors had been put in operation. This was accomplished in the 6000-h.p. and the 2000-h.p. motors at 68 rev. per min. by attaching to the rotor spiders heavy cast-steel rims which could easily be removed and exchanged for rims of different weights.

On account of their triple speed the two 2000-h.p., 214-rev. per min. motors have separate flywheels weighing 100,000 lb. each. These flywheels are built up of riveted boiler plates, which do not permit of alteration.

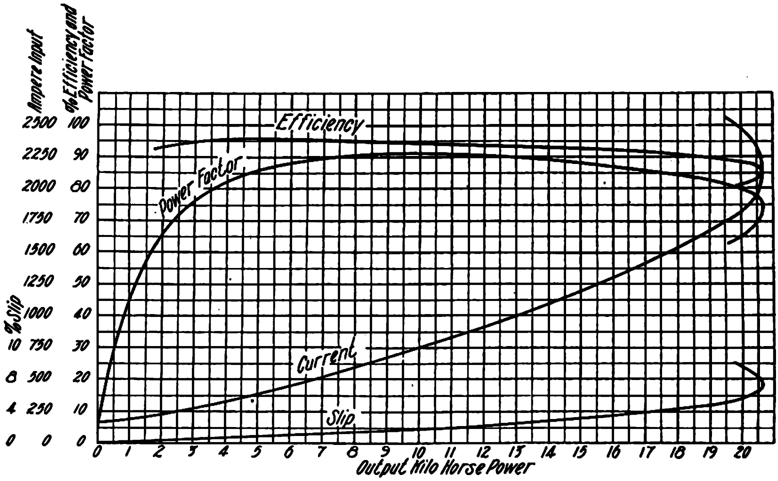


FIG. 26.—Characteristic curves of the 6000-h.p., 88-rev per min. induction motor.

The end-thrust which may result from a diagonal fracture of a spindle or roll is frequently sufficient to wreck either the mill or the motor unless special precautions are taken. This problem, which is extremely difficult to solve when an engine is used for driving the rolls, is very easily solved when electric motors are used. A device termed a mechanical fuse is attached to the pedestal by two breakable rods. These rods are so proportional that they will break only when the end-thrust exceeds 150 tons. When the rods give way under this pressure, the rotor is free to move longitudinally away from the rolls, thereby relieving the thrust. To prevent injury to the brush rigging, it is so arranged as to move freely with the brushes, always maintaining their proper position on the collector rings.

The bearings are self-aligning, with oil-ring lubrication. They can also be lubricated from an independent oiling system. Provision is made for water cooling in case of emergency.

The coils, which are assembled in open slots, are very rigid. In order, however, to prevent any possible vibration due to excessive fluctuations of the current, the coils are also firmly laced to a rigid supporting ring.

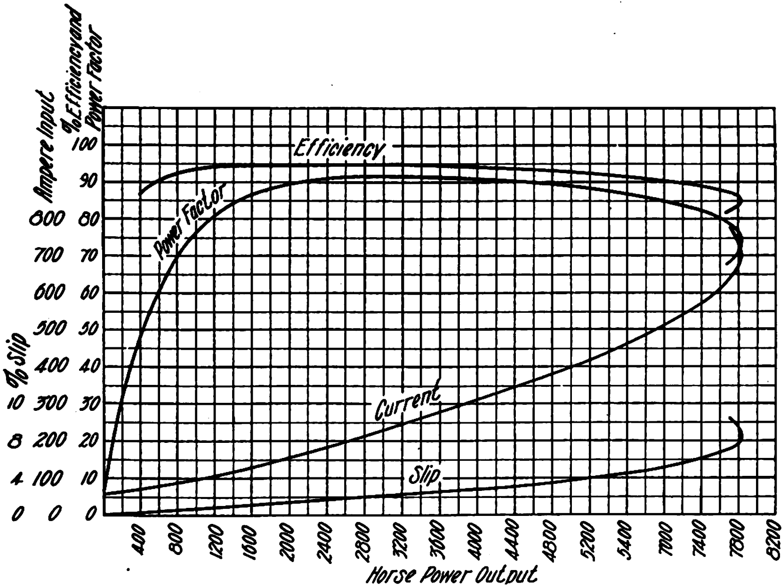


Fig. 27.—Characteristic curves of the 2000-h.p. 214-rev. per min. induction motor.

The electrical characteristics of the motors are shown by Figs. 26 and 27, which represent the results of tests of the 2000-h.p. motor at 214 rev. per min. and the 6000-h.p. motor at 88 rev. per min.

Reference to these curves shows that the power-factor and efficiency are near their maximum at the rated output of the motors, and that high values are maintained throughout the complete operating range.

The two 2000-h.p. 214-rev. per min. motors were received at the Gary Works complete except the flywheels, which were built up and turned after the installation of the motors. The three 6000-h.p. and one 2000-h.p., 68-rev. per min. motors were assembled and wound in position. The 2000-h.p., 214-rev. per min. motor with its controllers were tested before shipment, but the controllers for the remaining four motors were first assembled at the works.

Only two minor troubles have developed so far in the entire installation. On starting up one of the 6000-h.p. motors, one section of the rotor resistance overheated, but investigation proved this trouble to be due to a stray piece of arc-lamp carbon. In starting up another of these motors trouble developed due to a broken grid in the rotor resistance.

Control for roll-train motors. In designing the equipment for these 2000-h.p., and 6000-h.p., 6600-volt induction motors, not only were the sizes of the motors to be controlled beyond anything previously attempted, but the specifications presented many novel features.

For most of the motors the service required a very large flywheel effect. Because of the well-known characteristics of the induction motor, it was clearly recognized that there would necessarily be large fluctuations in current, even though the flywheels were very large, unless some means were employed for automatically introducing resistance into the motor circuit whenever the load was sufficient to cause even as small a change of speed as two or three percent. It was desirable that the automatic features be adjusted so as to operate continuously, regulating the current taken by the motors so that the demands on the source of supply for any one motor would be uniform—the motor and its flywheel, meanwhile, accelerating and decelerating at a point just below synchronism to meet the power demands of the rail mill which it was driving.

The large current in the secondary circuits of the motors necessitated separate contactors. Rheostats were arranged in multiple delta, and the successive value of the resistance was made such that as each contactor closed, the rush of current through it would be approximately one-fourth of the intake of the motor. This arrangement prevents the rheostats or contactors being called upon to carry anywhere near their full rated current, and gives the whole control system a conservative continuous rating.

The control apparatus for each motor consists of:

A. Preliminary control apparatus, which includes the oil switches, reversing switches, series transformers, preliminary relays, etc.

B. Secondary control, comprising the rheostats, contactors, regulating panel, etc.

C. Master controller.

Reference to the plan of the plant shows that the motors and the controlling apparatus are placed in a separate room, which is separated from the rolling mill proper by a partition. The master controller, however, is in the rolling mill. Under these conditions, therefore, the operator must depend chiefly on the automatic features of the control, which are so far away that he must judge of their correct working by the behavior of the rolls while the steel is passing through them. In case of emergency provision is made for the motor attendant to shut down the motors independently of the master controller.

The 6600-volt circuit enters through the triple-pole main oil-switch; from thence it passes through a number of oil-switches which determine the direction of rotation. These switches are interlocked, making it impossible for them to be operated unless the main switch is open. Additional interlocks prevent them from being closed simultaneously.

This group of preliminary-control apparatus also includes the necessary relays to open the circuit in case of overload and to prevent the secondary control from being operated in an injurious manner.

The arrangement of the secondary-control rheostats in multiple delta is shown in Fig. 31. Direct current at 250 volts was adopted, for the control of this secondary apparatus, and the voltages so arranged that each contactor coil is subjected to a pressure of only about 15 volts. This pressure is so small that the arcing is insignificant. To compensate for the different number of contactors in circuit at different speeds, a balancing resistance equaling the resistance of the contactor is cut in or out of circuit inversely as the contactor. This keeps the current in the contactor circuit approximately constant at about 5 amperes, and results in a simple arrangement of contacts on the regulating device. The regulating device consists of two concentric groups of buttons, one connected to the contactor coils and the other group to the contactor resistances, the two groups being cross-connected, step by step, by a simple arm controlled automatically. Should the 250-volt supply fail, a weight attached to the grooved pulley on this arm serves to return the mechanism to the off position. The master controller which operates both the preliminary-control and secondary-control apparatus has two handles; one is a reversing handle, and the other is for applying and shutting off the power.

The rail mill. The rail mill has a capacity of 4000 tons of finished rails per 24 hours. It is not only the largest, but also the only motor-driven mill in the world rolling rails directly from the ingot without reheating.

There are nine passes in the blooming mill. The first two passes are two-high rolls, 42 in. pitch diameter running at 6 rev. per min., and are connected to one of the 2000-h.p., 214-rev. per min. motors through gear reductions. The next two passes are identical with passes one and two, except that the rolls are 40 in. in diameter and make 10 rev. per min. and are driven in the same manner. The next five passes are made in a 40-in. three-high train direct-connected to a 6000-h.p., 75-rev. per min. motor. The lifting table for this train has already been described.

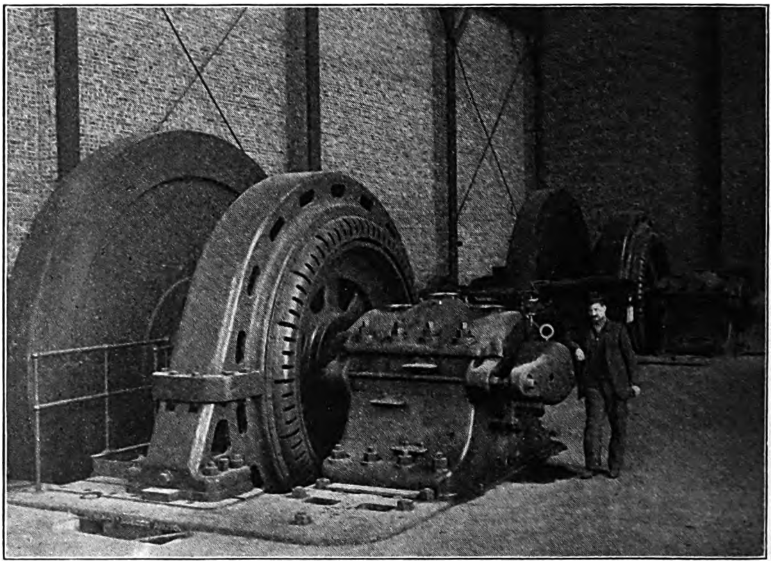


FIG. 28.—The 2000-h.p., 214-rev. per min. induction motor, which drive passes 1, 2, 3, and 4.

The bloom as delivered from pass 9 is then cut in two by means of the bloom shears, operated by a 75-h.p. induction motor.

The next train of rolls, which comprises a three-high roughing mill with passes 10, 11 and 12, is operated by means of the tilting table, the second edger or pass 16 and leader or pass 17. This train is 28-in., pitch diameter and direct-connected to a 6000-h.p. motor running at 63⅓ rev. per min.

The next pass is the 28-in. two-high former, direct-connected to a 2000-h.p., 68-rev. per min. motor.

The third roll train consists of the dummy, or pass 14; the first edger, or pass 15. and the finisher, or pass 18. These rolls also are 28-in. pitch diameter and the train is direct-connected to a 6000 h.p. 88 rev. per min. motor.

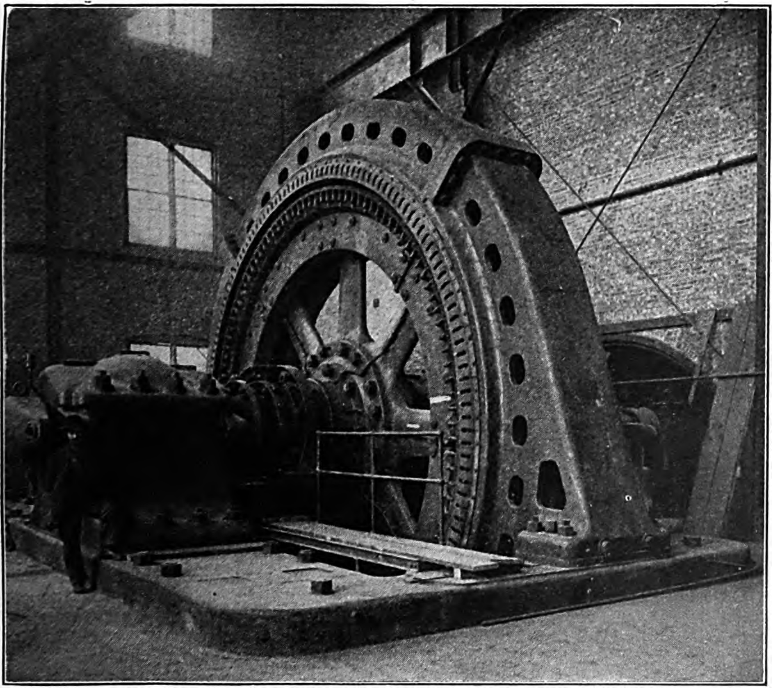


Fig. 29.—The 6000-h.p., 75-rev. per min. induction motor, which drives passes, 5. 6, 7, 8, and 9.

A diagram of these passes, together with the approximate shapes of the pieces leaving them, are shown in Figs. 32 and 32a, on which is also shown the table giving the size of the pieces leaving the various passes, the area in square inches, the weight per linear foot, percentage of reduction, length of piece, and horse power per pass—all as observed in the rolling of the first rail, which was an 80-lb., 33-ft. rail.

To supply power to the train motors of this mill there are two circuits, each of 10,000-kw. normal capacity at 6600 volts. One circuit feeds the three blooming-mill motors; that is. two 2000-h.p. and one 6000-h.p. The other circuit feeds the other three motors; that is, two 6000-h.p. and one 2000-h.p.

The estimated combined load with the mill working at full capacity, with voltage and amperage of each of the circuits, is shown in Fig. 33.

In originally designing the mill careful calculations were made of the time and horse power required to operate each pass. These data, with the calculated interval between passes, are shown clearly in Fig. 34. It will be noted on the right-hand side of this curve that there are both solid and dotted areas. The dotted area represents the second piece of the ingot after it had been cut at the bloom shears between passes 9 and 10, and the load estimated with the second piece in pass 10, while the first piece is yet in pass 12. Though it is improbable that such conditions will exist except in cases of the most rapid rolling, it was thought advisable to use them in the calculations of the mill. These calculations determined not only the total

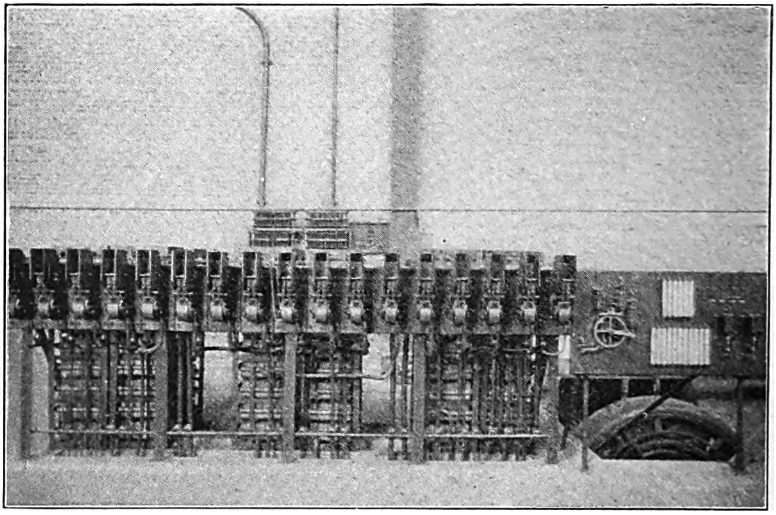
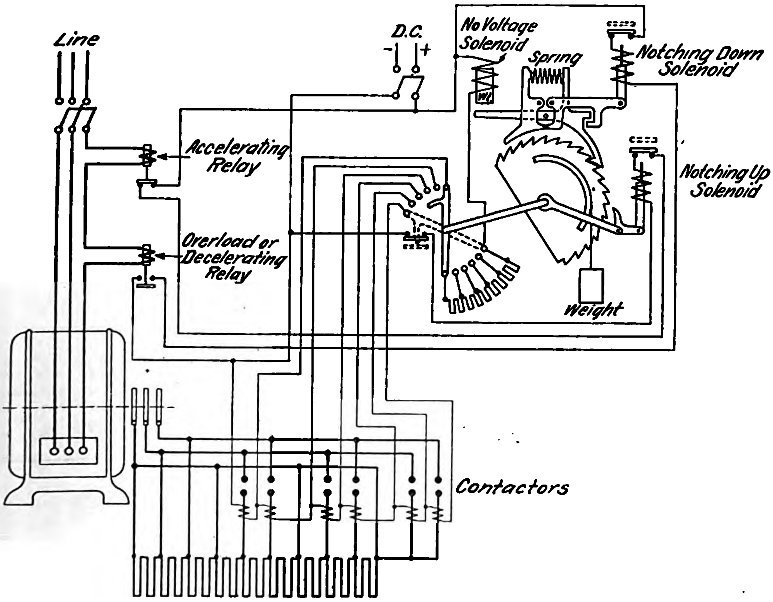


FIG. 30.—Secondary control for the 6000 h.p., 75 rev. per min.

time consumed by the ingot from start to finish, but also the shortest possible time between ingots, the limiting time being in the three-high roughing mill.

These curves were then superimposed on each other at this interval, which was 31.89 sec., until the number of ingots was increased to the maximum load on the mill. Adding the ordinates under this condition Fig. 33 was produced, showing the integrated load carried by the motors. The shaded portion indicates motor and line losses, and the upper line of the curve shows the character of the load on the power station.

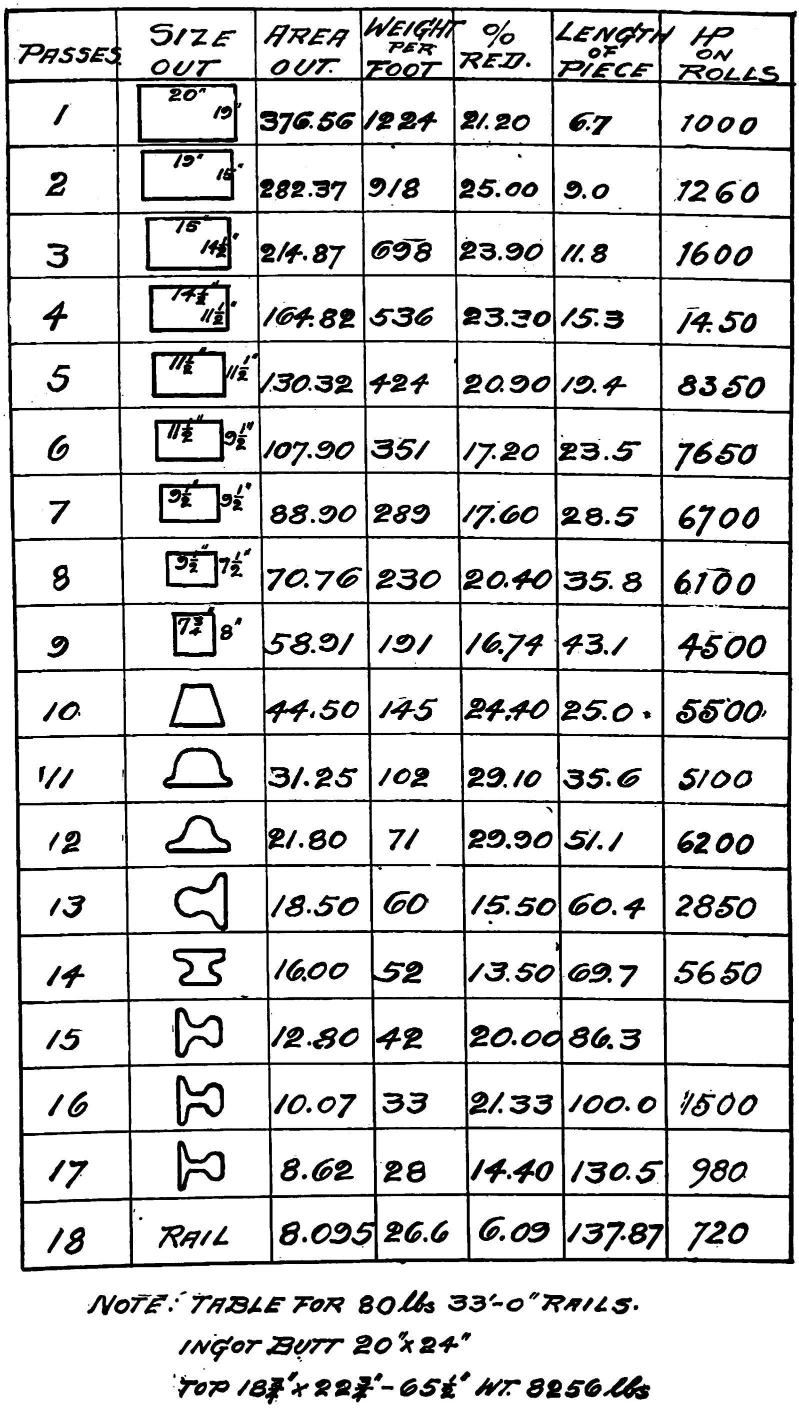

Line
D.C.
- +
No Voltage Solenoid
Spring
Notching Down Solenoid
wt
Accelerating Relay
Notching Up Solenoid
Overload or Decelerating Relay
Weight
Contactors

Simplified Control Connections for 6000 H.P. Induction Motor.

FIG. 31.—Diagram of secondary control of the rail-mill motors.

This cycle, which is 31.89 sec. indicates an exceedingly variable load, the total variations being from a minimum of 4300 h.p. to a maximum of 19,010 h.p. with an average of 12,025 h.p., which makes the load factor on the six-train motors almost exactly 50 per cent. The curve was developed to provide a basis for estimating the size of the storage-battery necessary to take care of the fluctuations and keep a constant load on the generating station.

Conclusions. One of the most satisfactory conclusions, so



PASSES	SIZE OUT	AREA OUT	WEIGHT PER FOOT	% RED.	LENGTH OF PIECE	HP ON ROLLS
1	20" 19"	376.56	1224	21.20	6.7	1000
2	19" 15"	282.37	918	25.00	9.0	1260
3	15" 14½"	214.87	698	23.90	11.8	1600
4	14½" 11½"	164.82	536	23.30	15.3	14.50
5	11½" 11½"	130.32	424	20.90	19.4	8350
6	11½" 9½"	107.90	351	17.20	23.5	7650
7	9½" 9½"	88.90	289	17.60	28.5	6700
8	9½" 7½"	70.76	230	20.40	35.8	6100
9	7¾ 8"	58.91	191	16.74	43.1	4500
10		44.50	145	24.40	25.0	5500
11		31.25	102	29.10	35.6	5100
12		21.80	71	29.90	51.1	6200
13		18.50	60	15.50	60.4	2850
14		16.00	52	13.50	69.7	5650
15		12.80	42	20.00	86.3	
16		10.07	33	21.33	100.0	1500
17		8.62	28	14.40	130.5	980
18	RAIL	8.095	26.6	6.09	137.87	720

NOTE: TABLE FOR 80 lbs 33'-0" RAILS.

INGOT BUTT 20"×24"

TOP 18¾"×22¾"-65½" WT. 8256 lbs

FIG. 32A

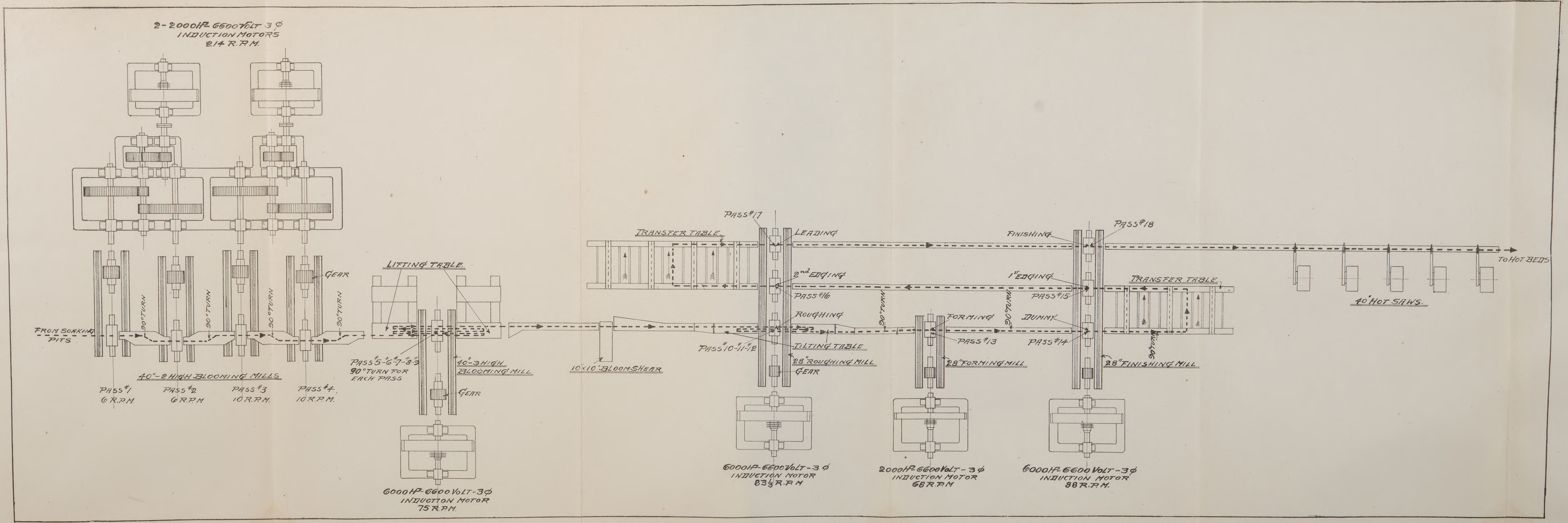

2-2000HP-6600 VOLT 3φ
INDUCTION MOTORS
214 R.P.M.
GEAR
90°TURN
90°TURN
90°TURN
90°TURN
FROM SOAKING PITS
40"-2 HIGH BLOOMING MILLS
PASS #1 6 R.P.M.
PASS #2 6 R.P.M.
PASS #3 10 R.P.M.
PASS #4 10 R.P.M.
LIFTING TABLE.
PASS #5-#6-#7-#8-#9
90° TURN FOR EACH PASS
40"-3 HIGH BLOOMING MILL
GEAR
6000 HP-6600 VOLT-3φ
INDUCTION MOTOR
75 R.P.M.
10"×10" BLOOM SHEAR
TRANSFER TABLE.
PASS #17
LEADING
2nd EDGING
PASS #16
ROUGHING
PASS #10-#11-#12
TILTING TABLE
28" ROUGHING MILL
GEAR
6000 HP-6600 VOLT-3φ
INDUCTION MOTOR
83⅓ R.P.M.
90°TURN
FORMING
PASS #13
28" FORMING MILL
2000 HP-6600 VOLT-3φ
INDUCTION MOTOR
68 R.P.M.
90°TURN
FINISHING
PASS #18
1st EDGING
PASS #15
DUMMY
PASS #14
28" FINISHING MILL
TRANSFER TABLE.
90°TURN
6000 HP-6600 VOLT-3φ
INDUCTION MOTOR
88 R.P.M.
40" HOT SAWS.
TO HOT BEDS

Fig. 32.—Plan of the rail mill

far as the Indiana Steel Co. is concerned, that can be drawn at the present date is that so far all of the apparatus described in this paper, which has been tried out, has been practically a perfect success. Nothing has occurred to indicate that there is any necessity of changing anything to a radical extent. As an example of this, the ore-handling machinery was started up July 23, 1908, and by Nov. 1, three-quarters of a million tons of ore were stored in the yard, with virtually no more trouble from the machinery than would have been experienced at a works which had been in operation for several years.

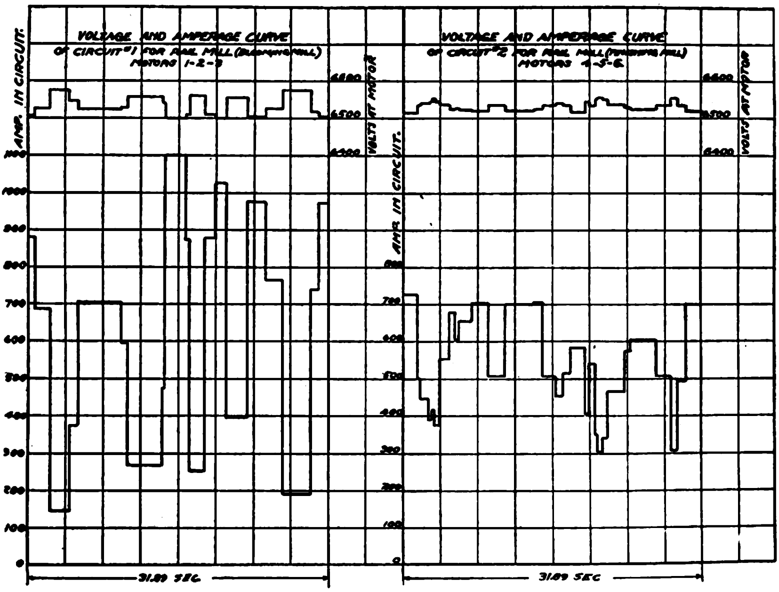


Fig. 32B

In the original design of the plant considerable attention was given to the question of underground versus overhead transmission. In view of some later developments although it might have been possible to put in underground service, which would not have greatly exceeded the cost of overhead construction, yet the latter has given no trouble. On the night of Jan. 29, during one of the severest wind storms ever experienced in this section, the velocity of the wind being estimated at over 70 miles per hour, not a single case of trouble occurred on the lines within the plant.

As stated in the description, all of the 6600-volt feeders were protected by multigap lightning-arresters, while the 22,000-volt has both multigap and electrolytic lightning-arresters. The latter were not installed until after the former had been operated for some time, and since the installation of the electrolytic lightning-arresters there has been no discharge over the multigap, nor have there been any bad effects from lightning either in

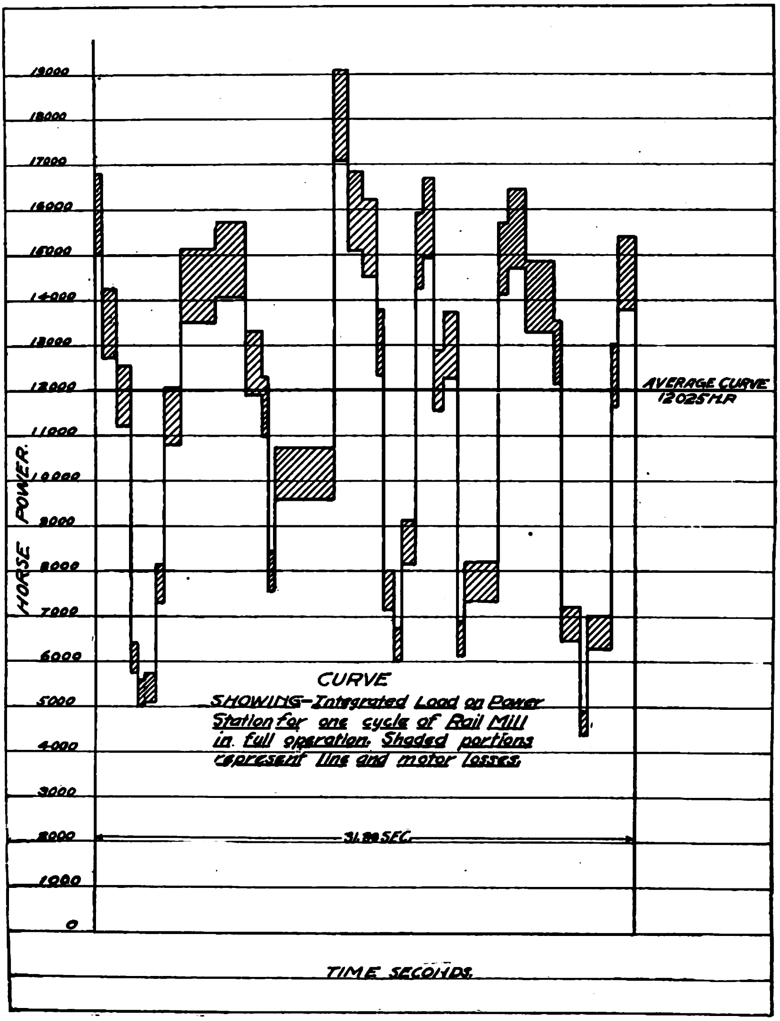


FIG 33.—Chart showing estimated combined load on the mill.

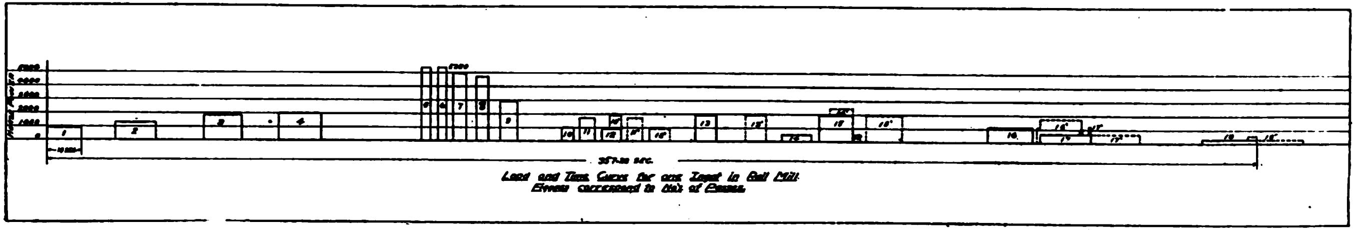


FIG. 34.—Chart showing calculated time and horse power per pass.

the plant of the Indiana Steel Co. or at other points on the line, which are protected in like manner.

In open-hearth plants No. 1 and No. 2 one feature not adopted in No. 3 and No. 4 will be the use of a large number of electric motors for operating the gas and air valves and furnace doors which had previously been worked by hydraulic pressure. This will leave simply the tilting of the mixer as the only piece of apparatus in the open-hearth plant not operated electrically; and the possibilities are that even this will be changed.

A comparison between the estimated horse power and the observed horse power required for the various passes in the rail mill shows some discrepancy; but because the steel rolled was colder than it would have been in actual practice, since all of the machinery is new and is not operating so quickly as it should, and because also the lack of adjustment of rolls, it is believed that the power required will be very little, if any, in excess of the original calculations. After the roll-train motors had been started it was discovered that the stopping of them was an important feature. The 2000-h.p., 214-rev. per min. motor when disconnected from the rolls required 2 hr. to come to rest, while the 6000-h.p., 83⅓ rev. per min. motor required 1 hr. and 37 min. to stop. This time consumed would mean corresponding delays in case of breaking of the main spindle, which, of course could not be countenanced. In order to stop these motors within a reasonable length of time, direct current at 250 volts was intro-

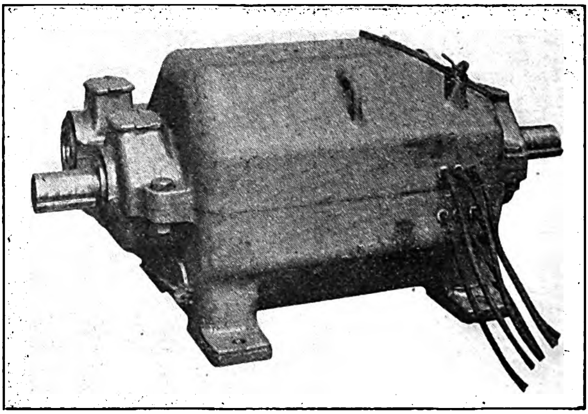


Fig. 36.—Mill type induction motor.

duced into one phase of the winding through an external resistance after the motor had been disconnected from the 6600-volt line. By this device the 2000-h.p., 214-rev. per min. motor was stopped in 2 min. and 55 sec., and the 6000-h.p. motor in 1 min. and 42 sec. During this time the first section only of the resistance of the rotor was closed. This device is being put in permanently, and a 6600-volt switch connected to one phase, the other side of which will be connected to the 250-volt line through a permanent resistance, and this switch interlocked with the main 6600-volt oil-switch so that both cannot be thrown in at the same time.

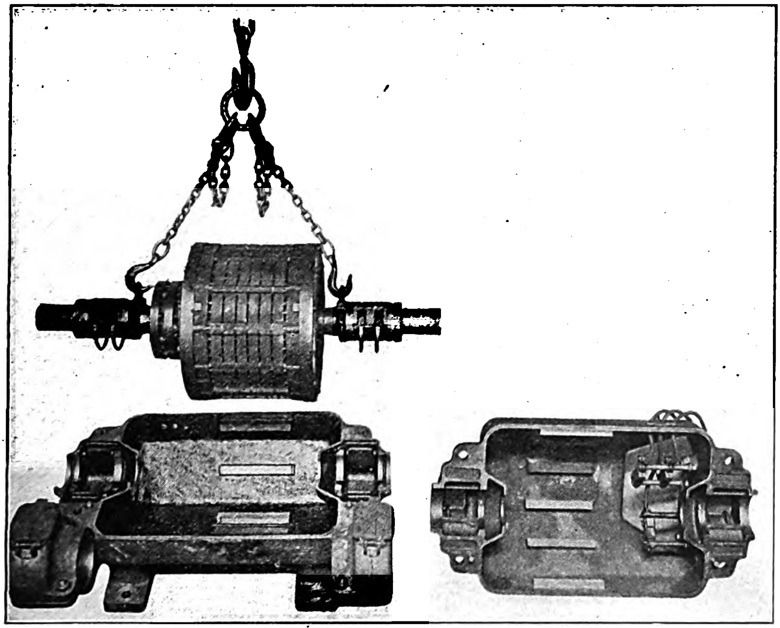


Fig. 37.—Dis-assembled view of mill-type induction motor.

Probably no industrial application of electricity has been the result of more careful study on the part of the engineers in charge, or has marked a more general adoption of electric power than the one just described. Although many of the motor applications are not new, this plant is unique in respect to the number and variety of the applications and the size of many of its units. The rail mill now in operation, driven by induction motors with a combined capacity of 24,000 h.p., and having a normal output of 4000 tons of steel rails per 24-hr. day, is without a rival. The operation of the plant will therefore be watched with more than usual interest, both by steel-mill engineers and electrical engineers. Its success will greatly accelerate the application of the electric motor in this industrial field.

Results thus far obtained indicate that not only have the greatest expectations of the engineers been realized, but another stronghold of the steam engine has been carried, and that in the near future the rolling-mill engine is destined to give way to its successor—the electric motor.

NOTE.

The following paper is to be read at the regular meeting of the American Institute of Electrical Engineers in **New York City, April 9, 1909.** This meeting is to be held under the auspices of the High-Tension Transmission Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

In contributing to a discussion, whether verbally or in writing, it is requested that the matter under discussion be taken up in the order followed in the paper, and that, after having dealt with the matter of the paper, there be introduced any other matter which the contributor may deem desirable. When contributions are made by mail on more than one of the topics under consideration at the same meeting, it is requested that the several topics be dealt with in separate letters.

Contributions will be read at the meeting for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the papers so far in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion.

Contributions to the discussion of this paper should be mailed to **Ralph D. Mershon, Chairman High-Tension Transmission Committee, 60 Wall Street, New York,** so that they will be received not later than April 5, 1909.

A paper to be presented at the 236th meeting of the American Institute of Electrical Engineers, New York, April 9, 1909

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(Subject to final revision for the Transactions.)

CONDENSER TYPE OF INSULATION FOR HIGH-TENSION TERMINALS

BY A. B. REYNDERS

The manufacture of apparatus for pressures of 88,000 volts or more resolves itself into the proper selection and arrangement of insulating materials. Of all the problems involved in this selection and arrangement, that of insulating the terminal wires where they pass through the case presents the greatest difficulty. When the terminal wires are carried through a metal cover the danger from breakdown is increased, yet the tendency of the latest designs is toward the use of metal tanks and covers. Even with present voltages the greatest difficulty lies in bringing out the terminal wires through the case. What may be termed " brute force " has characterized the proportioning of high-tension terminals up to the present time, as almost every class of insulating material in nearly every possible shape has been used to surround the conductor as it passes through the top of the case. The top itself has often been made of insulating material such as wood, simply to assist in insulating the lead.

One convenient way of analyzing the terminal problem is to consider it as a short piece of cable. The failure of such a terminal can occur in two ways; namely, by a puncture through the insulating material separating the inside conductor from the outside conductor or support, or by " creeping " over the surface from the end of the inside conductor to the end of the outside support.

Jona in an article on " Insulating Materials in High-Tension Cables " read before the International Congress at St. Louis in 1904, shows how the distribution of stress varies throughout the dielectric, being inversely proportional to the radius. Furthermore, he shows that by grading the material according to its specific inductive capacity, it is possible to make the stresses nearly uniform throughout the dielectric.

Fig. 1 shows graphically the potential gradient in an insulated cable for a homogeneous material. This shows clearly the distribution of the stress. The ideal condition is obtained when the potential gradient is a straight line.

By the introduction of layers of different materials with specific inductive capacities decreasing from the center outward, Jona obtains the result approximately as shown in Fig. 2, line *A C*. The curve *A B* is the same as in Fig. 1. By this method failure due to puncture in a properly designed cable is practically eliminated, but if the use of a piece of such a cable as the outlet lead from a transformer or a circuit-breaker is attempted, the greatest difficulty would be from breakdowns over the surface by "creepage" from the support to the ends.

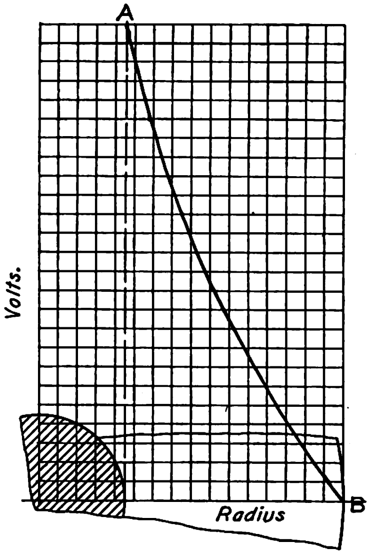

FIG. 1—Cable with homogeneous insulation; potential gradient through dielectric

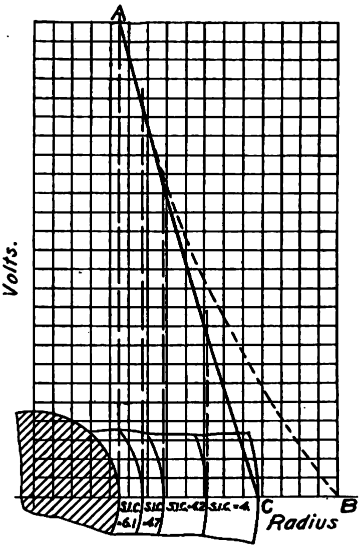

FIG. 2—Cable with graded insulation; potential gradient through dielectric

A method that takes care of both puncture and creepage has been proposed by Ryan, Smith, Nagel, and others. This method consists in dividing the dielectric by means of metal plates into a series of condensers of fixed capacities; for it is a known fact that if a difference of potential is impressed across a number of condensers connected in series, each will take its share of the stress in inverse proportion to its capacity. This principle has been utilized in constructing a terminal consisting of a small center rod or tube just large enough to carry the current, the rod being surrounded by alternative concentric cylinders of insulation and metal having the ends tapered in steps as shown in Fig. 3. The distribution of stress or potential gradient through the dielectric owing to the metal layers has been changed from a curve as shown in Fig. 1 to a straight line as shown in Fig. 2. Furthermore, the ends of the metal layers fix the distribution of voltage over the surface, which thus can be kept within safe limits. This design may be designated as a condenser type of terminal.

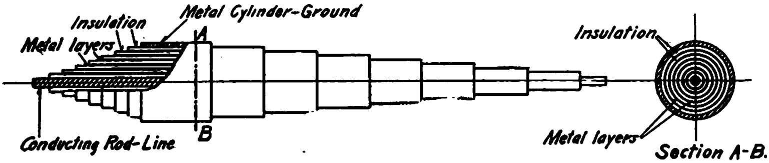

FIG. 3—Condenser type of terminal

Before considering the mechanical design of this type of insulated terminal, it would be well to dwell on a few fundamental facts that will limit the design. It is obvious that in order to obtain the maximum efficiency from the insulating material every part of it should be subjected to a stress proportional to its strength. Further, if the dielectric material is homogeneous throughout, every particle should be strained the same as every other particle. This means that in a series of condensers employing a homogeneous dielectric throughout, each one should have the same capacity as every other one. In order to obtain this desirable result various difficulties must be overcome. It is the purpose of the following to show how this can be done.

The formula for the capacity of two concentric cylinders is:

$$C = \frac{k\,l}{2 \cdot \log \frac{r_2}{r_1}}$$

where

C = capacity in electrostatic units

k = specific inductive capacity of the dielectric.

l = length in centimeters of the conducting cylinders.

$r_1 - r_2$ = radius in centimeters of the inside and the outside conducting cylinders, respectively.

A glance at this formula shows that the capacity may be varied by changing either the thickness between the conducting cylinder, the length of the conducting cylinders, or the specific inductive capacity of the dielectric.

It is now very generally known that the dielectric strength of ordinary solid insulating material does not increase proportionally as the thickness is increased. For this reason it is evident that to vary the distance between the cylinders in order to secure equal capacities will cause some layers to be thicker than others, and hence there is a waste of material.

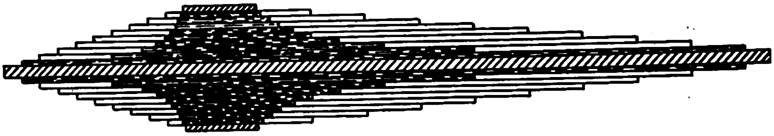

Fig. 4—Condenser type of terminal. Layers of insulation of equal thickness. Shaded portions show equal capacities throughout. Full lines show equal capacities on inside and outside layers and capacities, diminishing towards center of insulation thickness

The second method of varying the capacity—by changing the length of the conducting cylinder—is determined approximately, when equal capacities in all condensers are desired, by making the surface area, or the product of the length by the diameter, equal for all conducting cylinders. When the diameters of adjacent layers are nearly equal—a condition approached as the diameters increase—and the thickness of insulation remains constant, the ends of the layers come very close together, and failure is liable to occur by creepage. In other words, the most economical design for creepage is to make equal steps with an equal difference of potential between the ends of each step. This cannot be accomplished by varying the areas alone, as shown by reference to Fig. 4. The shaded portion shows the shape which the ends must have for equal areas, while the full straight lines show the shape the ends must have if equal steps between layers are obtained. The best compromise that can be obtained is to make the inside area and outside area equal and to allow all others to vary. The result is that the stresses are greatest at the center and on the outside, and decrease toward the middle.

The third means for obtaining equal capacity is limited by the variation in the specific inductive capacity of the available insulating materials. Unfortunately the available materials suitable for the manufacture of these terminals have very little variation in specific inductive capacity.

It is, however, by the combination of this third method with the best arrangement secured by the second method, that makes it possible to produce a terminal having equal distances and equal voltages between steps, and thus obtain the maximum economy from the minimum amount of material.

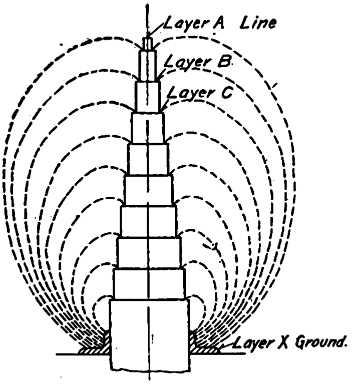

FIG. 5—Static field about condenser type of terminal

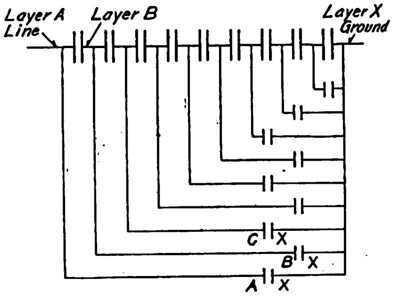

FIG. 6—Diagrammatic arrangement of condensers equivalent to Fig. 5

In all of the foregoing, only the capacity of the various metal plates with reference to each other has been considered, and it has been shown how it is possible to obtain equal capacities combined with other desirable features. If results on tests are to agree with previous calculations, there is one disturbing element which must be taken into account, especially at the higher voltages. This element is the capacity which each metal layer has to ground.

Fig. 5 shows in dotted lines what is possibly the static field surrounding a condenser type of terminal under service conditions. Fig. 6 shows an equivalent arrangement of condensers in which condensers *A-X*, *B-X*, etc., in parallel with portions of the main series, replace the leakages shown by dotted lines in Fig. 5.

Referring to these Figs., layers *A* and *B*, with dielectric material between, form a condenser which will be called condenser *A-B*. In addition, layer *A*, and the outside grounded layer *X*, with the intermediate air or oil as a dielectric, form a condenser, *A X*, which is in multiple with the remaining system of condensers. The only effect of this condenser is to cause corona at the edges of the center rod; that is, if the stress to ground is great enough. To reduce this corona to a minimum, all corners should be rounded, as will be explained later.

In a like manner, layer *B* and the grounded layer *X*, with the intervening medium as a dielectric, form a condenser, *B-X*, which is in series with condenser *A-B*, and in parallel with the remaining arrangement of condensers. Again, in similar manner condensers *B-X*, *D-X*, etc., combine their capacities with the remaining arrangement. The net result of this leakage capacity is to decrease the apparent capacity of the condensers *A-B*, *B-C*, *C-D*, etc., at the line end and to increase the capacities of the condensers at the ground end. In order to correct for the effect of this leakage, the calculated stresses at the ground end should be made greater than at the line end by a percentage determined by experience.

Terminals designed in accordance with the above principles are constructed by rolling up on a metal tube, paper and mica, or paper alone, using as a bond some material like shellac. At regular increases by steps in diameter, for example $\frac{1}{16}$ in., a layer of tinfoil, making one complete turn, is inserted during the rolling process. Great care must be exercised to obtain accurate diameters, especially when the thickness of insulation is small. No air spaces or wrinkling of the paper is allowable, or poor results will inevitably follow. After being completely wound, the tube is placed in an ordinary engine lathe and the ends tapered in steps, the amount of taper depending on whether the end is immersed in oil or surrounded by air. During this turning process careful work is necessary to prevent the turning tool from " digging " into the insulation below the tinfoil, owing to concentric layers of insulation being irregular in shape instead of true circles. After the turning process is completed, the entire terminal should be treated with some insulating varnish in order to prevent the absorption of oil into that portion projecting into the oil, and the absorption of moisture in that portion which is in air.

With a terminal constructed by the above method, there yet remains one point of weakness; namely, the edges of the tinfoil are sharp, and the potential which exists between these edges and ground may be high enough to cause corona effects in the surrounding medium. If this medium is air the result of corona will be the formation of nitrous acid or ozone, which may cause a deterioration of the insulating material and an ultimate breakdown. Up to the present time no harmful effects are known on insulation from corona in oil.

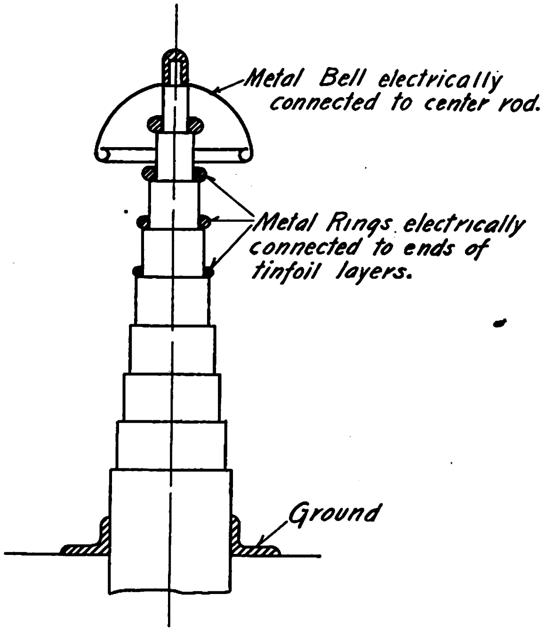
Metal Bell electrically connected to center rod.
Metal Rings electrically connected to ends of tinfoil layers.
Ground

FIG. 7—Arrangement for preventing corona at edges of tinfoil layers

It is virtually impossible to roll up a tube of insulating paper and tinfoil and obtain all layers concentric and true circles. This will be strikingly shown if the ends are tapered in a straight line. Moreover, with such ends, the tinfoil, which is usually of a maximum thickness of 0.0045 in., is drawn out to a sharp edge and hence the formation of corona by the breaking down of the air in contact with these edges is vastly increased. Again it will be found that there is no fixed surface distance between

the ends of the tinfoil layers, due to variations in the insulation between them. For these reasons these ends are always stepped instead of being in one straight line. Even with stepped ends, it has been found that with extremely high voltages, 250,000 and more, the tin-foil edges are sharp enough to cause the formation of corona. As shown by Jona, Ryan, Berg, and others, corona occurs when the stress on the small layer of air at the surface (edge of tinfoil) exceeds the maximum stress which the air will stand. The remedy for such a condition is to make the radius of the end of the tinfoil layer large enough to reduce the surface stress to safe limits. By referring to Fig. 7 it will be noted that this result is accomplished by adding a metal ring of suitable diameter at the corners where the tinfoil ends. This ring is electrically connected to the tinfoil. Furthermore, the addition of a metal bell of large diameter on the central rod at the top not only reduces corona from this rod, but acts as a shield or guard ring for the first few layers, with a resulting appreciable gain in the creepage strength of these layers.

Figs. 8 and 9 show photographs of two terminals under dielectric stress near their breaking point. Both are of the same dimensions throughout. Fig. 8 is the ordinary solid homogeneous type, while Fig. 9 is the condenser type using the same dielectric material as Fig. 8. The stress on the terminal Fig. 8 is 105,000 volts, while that on the terminal Fig. 9 is 200,000 volts. An examination of Fig. 9 shows no flashes on the lower five layers. This is due to these five layers being short-circuited in order to cause the remaining part of the terminal to flash at 200,000 volts, this being the only testing voltage available at that time. If these layers had not been short-circuited, the terminal would not have flashed at less than 225,000 volts.

Figs. 10 and 11 show two terminals designed for the same test of 200,000 volts for 1 minute. The dimensions will show the saving effected in using the condenser type of insulation.

The question naturally arises: If this style of insulation is effective for terminals, why could it not be used for the insulation throughout the transformer? The terminal proposition is one of concentric cylinders, and, if the particular insulation in the transformer is of a similar shape, there is no reason whatever why the condenser type should not be used; its effectiveness, however, is less and less as the diameters of the layers become greater, and the difference between diameters becomes less.

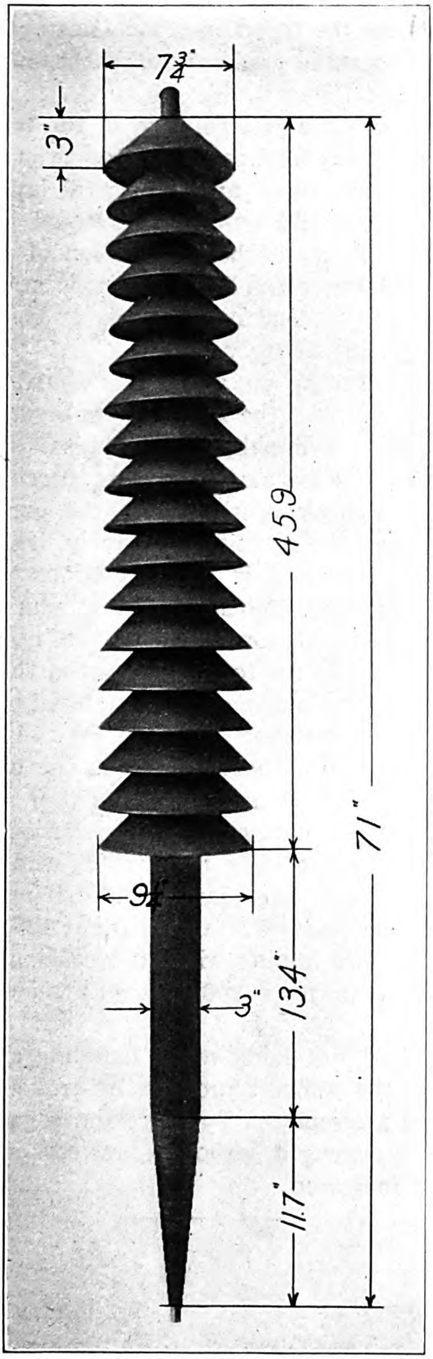
7¾"
3"
45.9
71"
9¼"
3"
13.4"
11.7"

FIG. 12—Outdoor type condenser terminal. Rain test: first spark 125,000 volts; intact at 150,000 volts, 1 minute; breakdown 200,000 volts

In other words, as the layers approach nearer and nearer to a flat surface the potential gradient approaches nearer and nearer to a straight line.

If the condenser type of insulation in the form of a tube is used between primary and secondary or primary and ground in a core-type transformer and the metal layers in the tube are connected electrically to points of equal potential in the windings, then not only is the distribution of stress in the dielectric fixed and hence the total dielectric strength increased, but the action of the condensers assists in the suppression of surges due to outside disturbances.

It is probable that by the use of the above method of connecting the winding and the metal layers together, and the use of condenser type of terminals, transformers of 300,000, 400,000, or 500,000 volts may be made on a commercial basis.

There is yet another possibility of the condenser type of terminal which may be mentioned; namely, its use for outdoor service. Such a terminal is constructed as mentioned above except that at the end of each metal layer is placed a bell-shaped metal cap in electrical contact with the metal layer. The space on the surface of the terminal between the caps is covered by a cylinder of porcelain or similar material. The completed terminal has the appearance shown in Fig. 12. This terminal without the bell-shaped metal caps has the same dimensions and materials as the terminal shown in Fig. 9. The metal caps vary in size, having a maximum diameter of 9.25 in. and a depth of 3 in. Upon test in a rain, falling at a rate of between 0.2 and 0.3 of an inch per minute, and driving horizontally at times, this terminal showed a faint spark at 125,000 volts, stood 150,000 volts for one minute with an occasional flash between caps, and broke down at 200,000 volts at the end of a few seconds.

Such a terminal will stand rough handling and will solve to a great extent the difficult problem of broken insulators. If the metal discs are replaced by porcelain, a gain will be made in the insulation strength, although first cost and maintenance will be greatly increased.

NOTE.

The following paper is to be read at the regular meeting of the American Institute of Electrical Engineers in **New York City, April 9, 1909.** This meeting is to be held under the auspices of the High-Tension Transmission Committee of the Institute. All those connected with the Institute and desiring to take part in the discussion of this paper may do so by being present at the meeting; or, if this is not possible, by sending in a written contribution.

In contributing to a discussion, whether verbally or in writing, it is requested that the matter under discussion be taken up in the order followed in the paper, and that, after having dealt with the matter of the paper, there be introduced any other matter which the contributor may deem desirable. When contributions are made by mail on more than one of the topics under consideration at the same meeting, it is requested that the several topics be dealt with in separate letters.

Contributions will be read at the meeting for which they are intended, either in full, in abstract, or as a part of a general statement giving a summary of the views of those taking the same position in the matter.

The principal object in getting out the papers so far in advance of the meeting is to enable and encourage those not in a position to attend the meetings to take part in the discussion.

Contributions to the discussion of this paper should be mailed to **Ralph D. Mershon, Chairman High-Tension Transmission Committee, 60 Wall Street, New York,** so that they will be received not later than April 5, 1909.

A paper to be presented at the 236th meeting of the American Institute of Electrical Engineers, New York, April 9, 1909.

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(*Subject to final revision for the Transactions.*)

HIGH-VOLTAGE TRANSFORMERS AND PROTECTIVE AND CONTROLING APPARATUS FOR OUTDOOR INSTALLATION

BY K. C. RANDALL

Outdoor or weatherproof transformers for ordinary distributing purposes, and for potentials up to about 2500 volts, have long been in general service. With the exception of arc lamps and series incandescent lamps, transformers have been about the only apparatus in high-tension service not protected by buildings. Distributing circuits operating at 6600 volts are now quite common. There are also a few 10,000-volt, and a small number of 15,000-volt distributing systems using outdoor transformers.

Thus far, about 50 kilovolt-amperes has been the limiting capacity found in outdoor service, but there are a few exceptions. Outdoor transformers of 100 kilovolt-amperes capacity or greater, for any voltage, have been almost unknown. Recently, however, large transformers have been taken up; a few are in service, and most of them but for a short time.

The outdoor problem may be divided into two parts:

1. The production of satisfactory outdoor apparatus.
2. The application of outdoor apparatus.

The design and construction will be discussed, and the application will be considered.

Construction. Transformers for outdoor service may be built for any requirements that the ordinary indoor type of oil-insulated unit will satisfy. As to capacity, the limit of approximately 500 kilovolt-amperes will apply to the self-cooled type, depending somewhat on voltage and frequency. As with the self-cooled indoor transformers, the case is the principal problem. It is difficult to obtain the radiating surface required for cooling very large transformers, and still retain a simple mechanical construction. Oil-insulated, water-cooled, outdoor transformers can be built for any capacity irrespective of voltage and frequency.

The first problem apparent in the development of outdoor transformers concerned the terminals: how to make them reliable in all kinds of weather and service. The next problem was satisfactorily to weatherproof the case. This much of the problem has been worked out, and now outdoor transformers up to 500 kilovolt-amperes capacity have been built, and units for potentials up to 60,000 volts are in service.

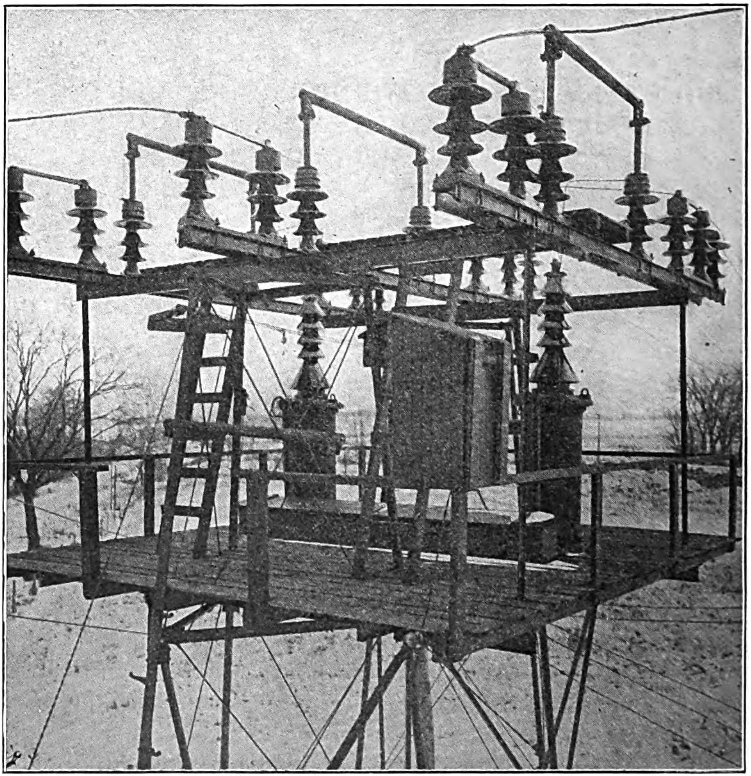

FIG. 1—Two 60,000-volt series transformers

The downward projecting lead which issues from an overhanging pocket near the top of the transformer case is a quite satisfactory construction for moderate potentials. 10,000 volts or more can better be carried by upward projecting terminals, this arrangement being particularly attractive for convenience in wiring. About the same practice for placing outlet terminals serves for both indoor and outdoor transformers, so far as the general arrangement and convenience are concerned. The essential requirements of outdoor terminals are that they retain their insulation characteristics and that they do not deteriorate by exposure to the elements. Outdoor terminals are larger and require much more room than those for indoor service.

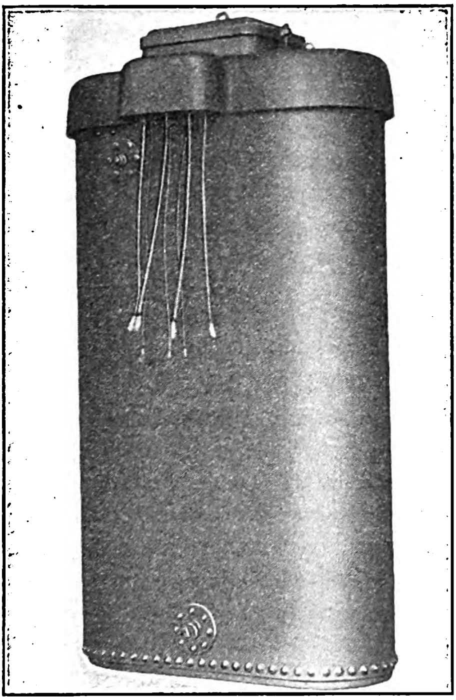

FIG. 2—This construction for outdoor service has been used for 6600-volt 25-cycle, three-phase transformers from 75 to 350 kilovolt-amperes

Fig. 10 illustrates a self-cooled 300-kilovolt-ampere, 33,000-volt, outdoor unit. The case is corrugated sheet-iron with welded vertical seams. The bottom and top are cast on the corrugated shell. The resulting construction is strong, oil tight, and is not subject to damage by the elements. The cover, also of cast iron, has a considerable overhang or eave to guard the joint between it and the top of the case, and is fitted with the outlet terminals and a small inspection door. All joints are protected by an overhang and are designed for making tight with gaskets.

Outdoor water-cooled units employ the same general construction as the self-cooled type, except that the cases will usually be of boiler iron, and cooling coils with connections must be provided.

Weatherproofing outdoor transformer cases is doubtless best done by making the joints vacuum-tight. Eliminating leaks means that nothing can enter, and therefore a clean, dry unit would remain in that condition. Moisture is the only enemy to be feared, either in the form of rain, snow, or humidity. The " breathing " of wet air is the most important source of trouble, because it is the hardest to eliminate. As a transformer heats, part of the air in the top of the case will escape if an outlet exist and new air will return as the initial temperature is resumed. Under certain conditions moisture which may have entered with the new air will condense. The amount of moisture which will accumulate in this way, in a short time, is quite surprising. Well-made gasketed joints, with deep, overhanging eaves and carefully sealed-in outlets give good results.

Application. Whether outdoor apparatus is really desirable, involves a great many points even after it is proved satisfactory in the individual piece. Some of the more important considerations are: location and climate; cost of building and ground for indoor station; cost of corresponding ground for outdoor station; capacity of station; high-tension and low-tension voltages; number of high-tension and low-tension circuits; method of operation and control; method of cooling; attendance and supervision; instruments and their housing; and the cost of indoor *versus* outdoor apparatus.

A 20-kilovolt-ampere, 2200- to 220-volt transformer immediately suggests a pole installation. But if the figures are multiplied by ten, a 200-kilovolt-ampere, 22,000- to 2200-volt transformer suggests indoor service. If these figures are multiplied by three, a 600-kilovolt-ampere, 66,000- to 6600-volt transformer certainly has always demanded housing.

The large clearance required for exposed high-tension wiring and disconnecting switches; the expensive construction demanded for enclosed high-tension wiring and switch structures; the cells or compartments often used for transformers; the space for protective apparatus—all these operate to make the high-tension station costly as compared with the low-tension station. If all high-tension apparatus were placed outside, some kind of a structure would still be required in most cases for housing the instruments, the high-tension control apparatus and the low-tension switchboard. If attendance were contemplated, some additional facilities might also be required. Under nearly all conditions where control of either or both high- and low-tension circuits is demanded, some housing will be required. Attendance, or at least frequent inspection, should usually be provided. When housing is needed for part of the apparatus, perhaps a large part, the expected advantage of placing the remaining apparatus outdoors may not become important, or may even not exist at all. In order to obtain the cost comparison the cost of the station grounds and indoor apparatus must be balanced not only against the smaller building, but also against all the ground required for the outdoor apparatus, the outdoor apparatus itself, and the instruments and the indoor control apparatus.

If the high-tension circuits are many, and switching is contemplated, the outdoor arrangement appears attractive. If the low-tension plan calls for the control of the several circuits, the indoor arrangement looks desirable, as but little additional indoor space over that required for the instruments and high tension control panels may be necessary for the low-tension switchboard. Furthermore, indoor low-tension switches and wiring, especially if remote control be not used, should be cheaper. Finally, when there has been provided a house that covers all but the high-tension pieces, it may be found that a small additional cost would have housed everything. Evidently no rule can be set down, as every case will require individual solution.

With all the large bodies of oil in such apparatus as the transformers and circuit-breakers outdoors and only instruments and remote-control boards indoors, the life and property hazard may be considered as less than in the equivalent but more congested indoor arrangement. The likelihood of careful inspection, however, is also much less, especially in bad weather. The difficulty of outdoor repairs except in the finest weather, is worthy of attention; though failures are very infrequent with well-built high-tension apparatus.

The successful outdoor transformer would itself be of less interest if outdoor switches and protective apparatus were not also available. Under such conditions, omitting the housing for the transformer might be of small advantage if protection for all other apparatus were still to be provided. The economy anticipated from employing outdoor transformers can generally be but partly realized without other outdoor apparatus.

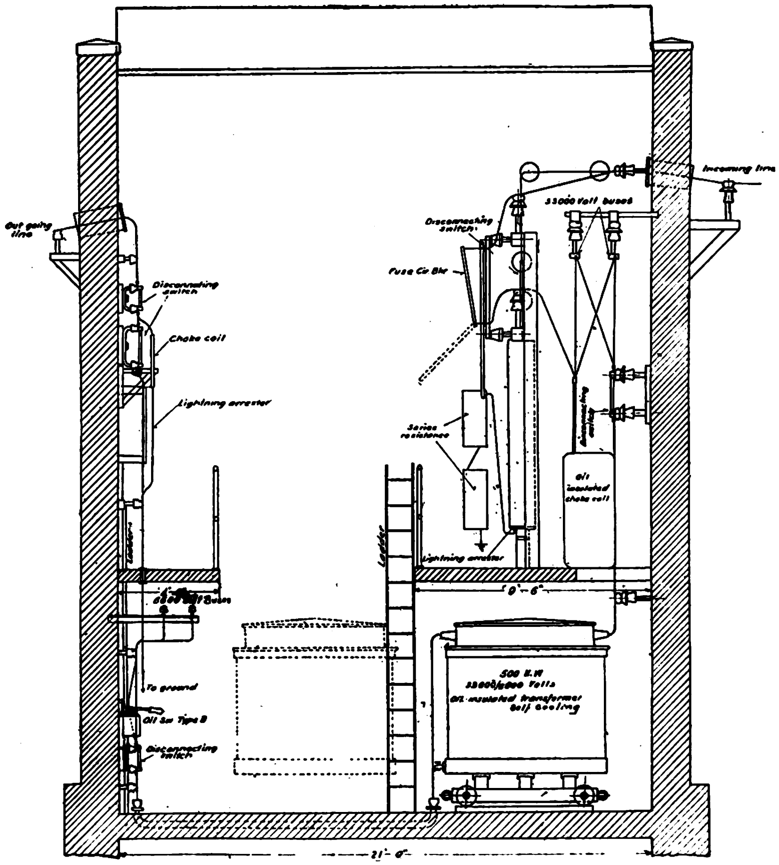
Out going line
Disconnecting switch
Choke coil
Lightning arrester
Ladder
6600 Volt Buses
To ground
Oil Sw Type B
Disconnecting switch
Incoming line
33000 Volt buses
Disconnecting switch
Fuse Cir Bkr
Series resistance
Lightning arrester
Disconnecting switch
Oil insulated choke coil
Ladder
8'-6"
500 K.W
33000/6600 Volts
Oil insulated transformer
Self cooling
21'-0"

FIG. 3—Sectional view of 1500 kilovolt-ampere, 33,000-volt to 6600-volt, 25-cycle transformer station

Fig. 3 shows an indoor 33,000-volt station and Fig. 4 shows an equivalent outdoor station, No instruments are employed and no attendance is required. The station is entirely without a building. Fig. 5 shows a 60,000-volt indoor station, and Fig. 6 shows an equivalent outdoor station of one-fourth the capacity. As an example of the growth toward outdoor stations, there may be cited the Lockport Station of the Niagara, Lockport & Ontario Power Company. Some of the illustrations of this station showing outdoor lightning arresters and 60,000-volt busbars have already appeared in the Institute TRANSACTIONS.*

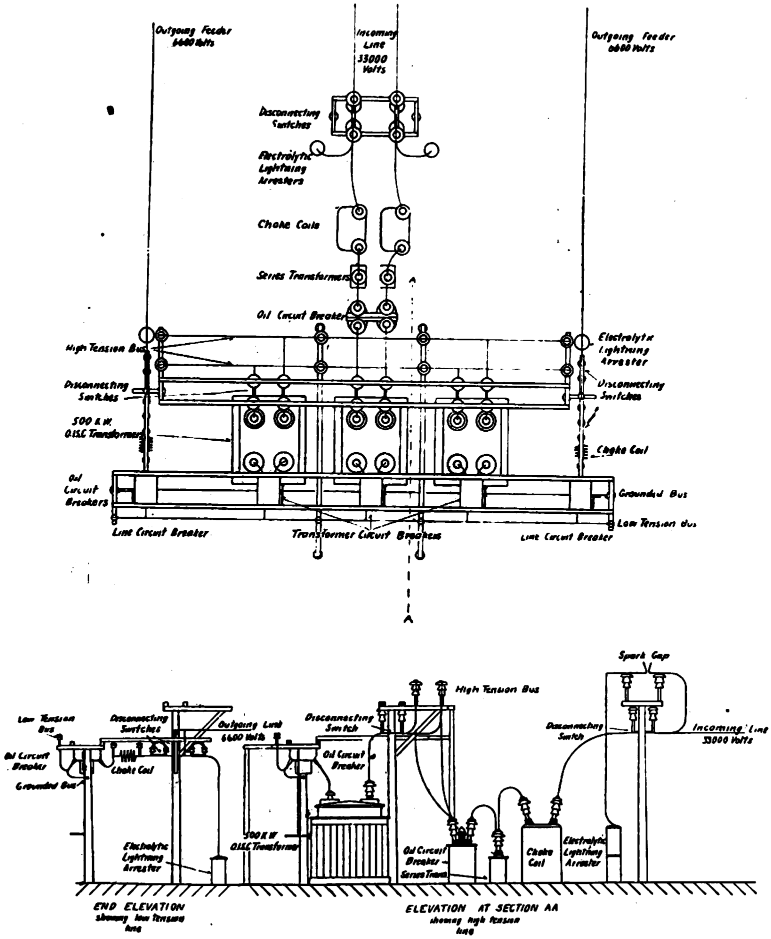
Outgoing Feeder 6600 Volts
Incoming Line 33000 Volts
Outgoing Feeder 6600 Volts
Disconnecting Switches
Electrolytic Lightning Arresters
Choke Coils
Series Transformers
Oil Circuit Breaker
A
High Tension Bus
Electrolytic Lightning Arrester
Disconnecting Switches
Disconnecting Switches
500 K.W. O.I.S.C. Transformers
Choke Coil
Oil Circuit Breakers
Grounded Bus
Low Tension Bus
Line Circuit Breaker
Transformer Circuit Breakers
Line Circuit Breaker
A
Spark Gap
High Tension Bus
Low Tension Bus
Disconnecting Switches
Outgoing Line 6600 Volts
Disconnecting Switch
Disconnecting Switch
Incoming Line 33000 Volts
Oil Circuit Breaker
Choke Coil
Grounded Bus
Oil Circuit Breaker
Electrolytic Lightning Arrester
500 K.W. O.I.S.C. Transformer
Oil Circuit Breaker
Series Trans.
Choke Coil
Electrolytic Lightning Arrester
END ELEVATION showing low Tension line
ELEVATION AT SECTION AA showing high tension line

FIG. 4—Illustrates an outdoor transformer station equivalent to the one shown in Fig. 3

Considered purely as a circuit-interrupting device, whether

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* Transactions A.I.E.E., 1907, Vol. XXVI, Part II, p. 1273.

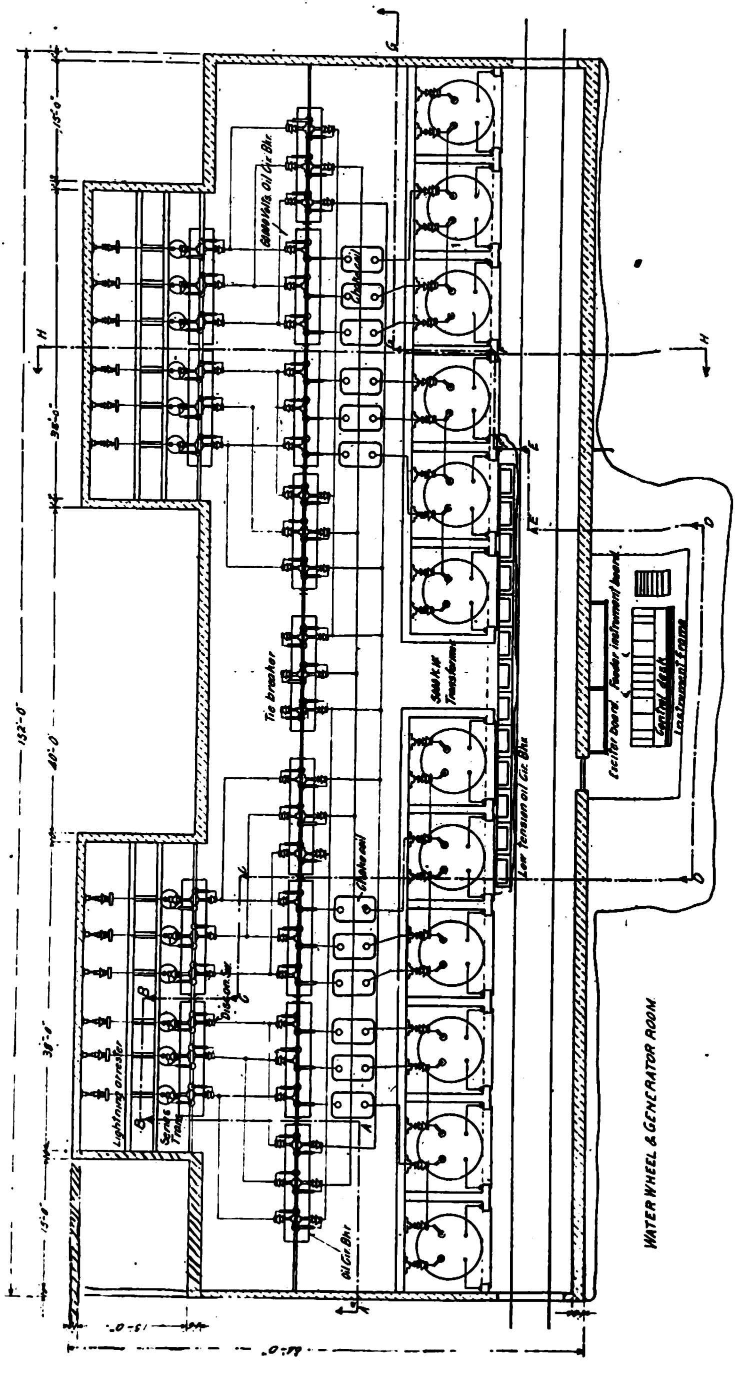
60000 Volts Oil Cir. Bkr.
Choke coil
Tie breaker
5000 K.W. Transformer
Low Tension oil Cir. Bkr.
Exciter board
Feeder instrument board
Control desk
Instrument Frame
Lightning arrester
Series Trans.
Discon. Sw.
Oil Cir. Bkr.
WATER WHEEL & GENERATOR ROOM
132'-0"
15'-0"
38'-0"
40'-0"
38'-0"
15'-0"
15'-0"
44'-0"
A
B
C
D
E
G
H

FIG. 5—Plan of 60,000-volt, 60,000-kilovolt-ampere, indoor transformer station

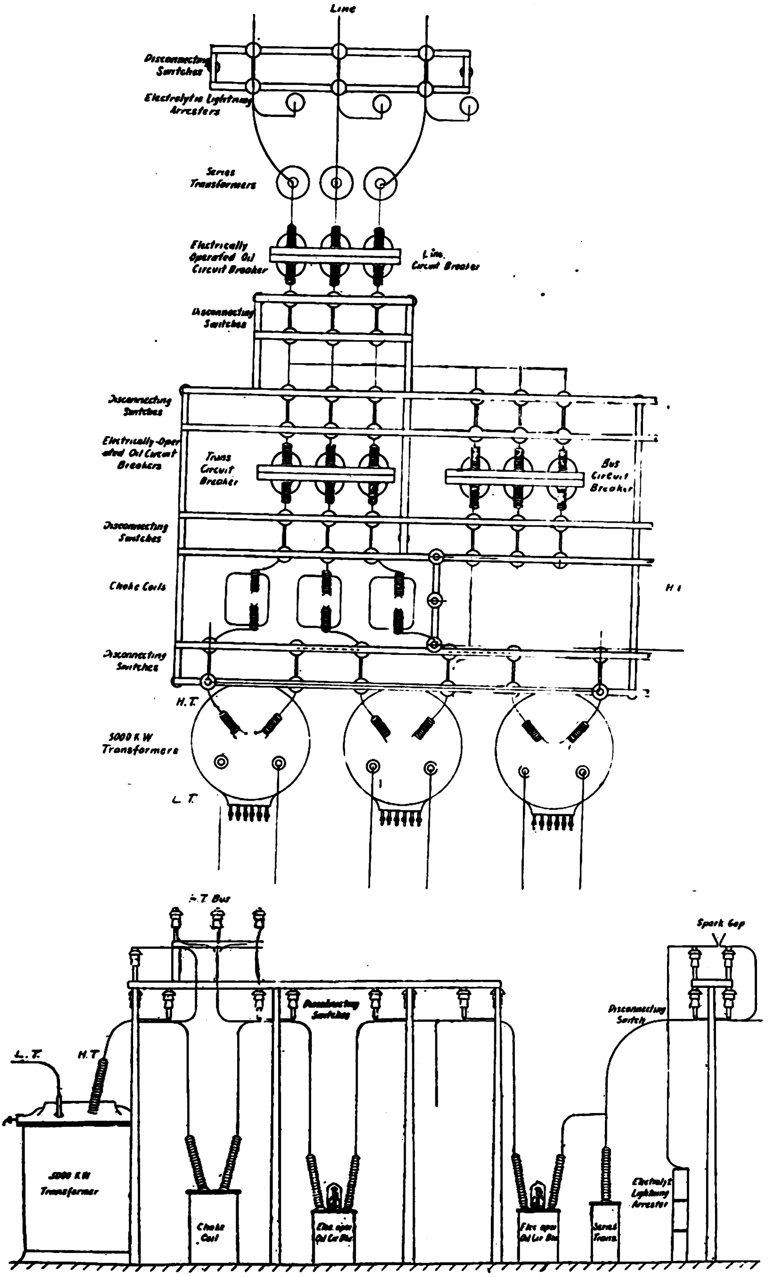
Line
Disconnecting Switches
Electrolytic Lightning Arresters
Series Transformers
Electrically Operated Oil Circuit Breaker
Line Circuit Breaker
Disconnecting Switches
Disconnecting Switches
Electrically-Operated Oil Circuit Breakers
Trans Circuit Breaker
Bus Circuit Breaker
Disconnecting Switches
Choke Coils
H
Disconnecting Switches
H.T.
5000 K.W Transformers
L.T.
H.T Bus
Spark Gap
Disconnecting Switches
Disconnecting Switch
L.T.
H.T
5000 K.W Transformer
Choke Coil
Elec. oper Oil Cir Bkr
Elec. oper Oil Cir Bkr
Series Trans.
Electrolytic Lightning Arrester

FIG. 6—Layout for outdoor transformer station, equivalent to one-fourth of indoor station, Fig. 5

a circuit-breaker operates indoors or out does not affect the requirements. Outdoor transformer construction will take care of case and terminals—a suitable enclosing hood readily removable to protect the mechanism from the elements, snow and ice particularly, completes the changes necessary to make an outdoor unit. Non-freezing oil should be used in order that operation in severe weather may not be endangered. The ordinary methods of operation such as remote control, overload release, etc., are available just as in indoor practice. Outdoor disconnecting switches are in common use, and outdoor fuses have also found favor in some places.

The horn-gap arrester has been used considerably in outdoor service, both at terminals and along the transmission line, and the electrolytic type has been installed both indoors and outdoors. Arresters for all transmission voltages and designed for outdoor use are now available. The considerable amount of space indoors required for high-voltage lightning-arresters, and its cost, are serious; in fact, arrester houses are not unknown. Outdoor types may therefore be of particular and almost independent interest.

Outdoor choke-coils differ from indoor choke-coils only in respect to case and terminals; if of the oil-insulated type, the outdoor-transformer construction will apply. It is noticeable that about the same structural problems and solutions apply to outdoor transformer circuit-breakers, and protective apparatus.

It has been suggested that by treating the high-tension transformer as part of the line, no high-tension circuit-breakers would be required and no high-tension lines need enter a building.[*] All switching would be done on the low-tension side, and when necessary fused disconnecting switches on the high-tension side would serve to cut off the transformer.

Outdoor stations should be paved and well drained around the apparatus. If this is considered too costly, individual foundations for each piece will serve. Transfer trackage with a truck, or a heavy hand truck will be found very convenient when moving apparatus.

When the stations are important it will usually be found desirable to arrange a room with repair facilities and connected with the outdoor station trackage, rather than resort to temporary weather protection or to remove the apparatus to a distance, should repairs be necessary. Such space would doubtless be convenient for many purposes such as cleaning and inspecting. Fencing, to keep out intruders, is advised when more than the bus-bars are outdoors.

The general use of outdoor apparatus to the exclusion of indoor apparatus is, of course, not to be expected; but frequent applications will doubtless be made as a development of the general type of station just referred to. Transformer and switching stations present the greatest opportunities, as power houses and sub-stations employing synchronous converters or

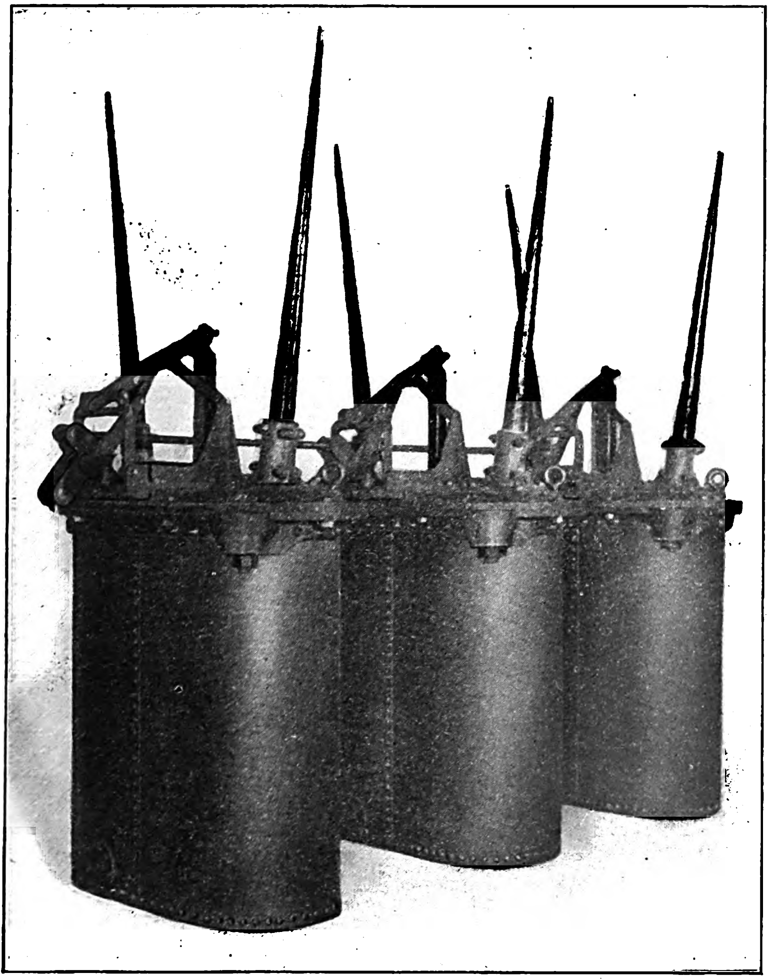

FIG. 7—Three-pole indoor, 60,000-volt, 300-ampere circuit-breaker

motor-generator sets require so much housing that indoor transformers, circuit-breakers, etc., may be considered best.

If power is to be used within a short distance of a transmission line, a single transformation to the service voltage will be best. When an extended distribution is to be fed, a secondary transformation to the service voltage should be employed. The outdoor transformer will serve in either place, but with existing primary transformations the smaller secondary transformation affords a particularly attractive field.

Costs. Outdoor transformers, like the indoor type, increase in cost as the operating voltage is raised, and decrease in cost as the frequency of operation is increased. It is common to prefer a few large transformers rather than several small units. Also large transformers for the transformation from the high transmission voltage, with several smaller units on a secondary system, are preferred to a number of small units serving the consumers by one transformation from the transmission voltage.

The following cost estimates based on existing installations—two equivalent indoor and outdoor 2000-kilovolt-ampere, 25,000-volt, 60-cycle stations—may be of interest.

Indoor station. High-tension apparatus inside of building. Transformers in pockets.

Approximate cost of steel building. frame erected	$3100
Inside of building, including steel work	2300
Total for building	$5400
Two 1000 kilovolt-ampere, three-phase, 22,000-volt to 440-volt, 60-cycle transformers delivered and erected	7200
Switchboard for above, including two incoming line panels step-down transformers panel, and necessary oil switches	2500
Total for station	$15,100

Outdoor station.

Building, including outside bus-bar structure	$1020
Two 1000 kilovolt-ampere outdoor transformers as above, delivered and erected	7800
Switchboard as above (only low-tension apparatus and panels inside) all high-tension bus-bars and transformers outside, delivered and erected	2625
Total for station	$11,445

From these figures, the indoor station costs approximately 30 per cent more than the outdoor station.

Another example covers the approximate costs of a 3000-

kilovolt-ampere, 22,000-3000-volt, 25-cycle motor-generator sub-station.

Indoor station. Incoming lines 22,000 volts, two of which are installed. Building structural steel, all apparatus inside, transformers in brick compartments. High- and low-tension bus-bars and oil switches in compartments.

Length of building 110 ft., width 38 ft., equalling 4180 sq. ft.	
Approximate cost of building ready for apparatus, steel work and compartments	$21,835
Three 1000-kilovolt-ampere, three-phase, 22,000/3000 volt, 25-cycle, step-down transformers, delivered and erected	15,000
Three 1000-kilovolt-ampere, motor-generator sets, motor synchronous type, 3000 volts operating at 80 per cent leading power-factor. Generator 550/600 volts, delivered and erected	48,000
Three 45-kw. exciters, induction motor driven, delivered and erected	4,500
Two incoming lines 22,000 volts, three-phase.	
Three three-phase 1500-kilovolt-ampere, step-down transformers panels 22,000/3000 volts.	
Two three-phase railway feeder panels 3000 volts, 3000 kilovolt-amperes.	
Four three-phase lighting feeder panels, 3000 volts, 500 kilovolt-amperes.	
Three panels for controlling motor-driven exciters.	
Three synchronous motor panels.	
One direct-current feeder and total output panel 600 volts, 3000-kilowatt switchboard delivered and erected	20,000

Recapitulation.

Building	$21,835
Switchboard	20,000
Transformers	15,000
Motor-generator sets	48,000
Exciters	4,500
Total costs	$109,335

Outdoor station. High-tension apparatus outdoors on concrete foundations. Building to be 110 ft. by 19 ft. Station same as above as regards output. Ordinary type of building. No steel work.

Building	$7,480
Switchboard, same as above. Oil switches made weatherproof	20,200
Transformers made weatherproof	16,000
Motor-generator sets as above	48,000
Exciters, as above	4,500
Total	$96,180

In this example, as might be expected, the saving of approximately 13 per cent is not so large as for the simple transformer station.

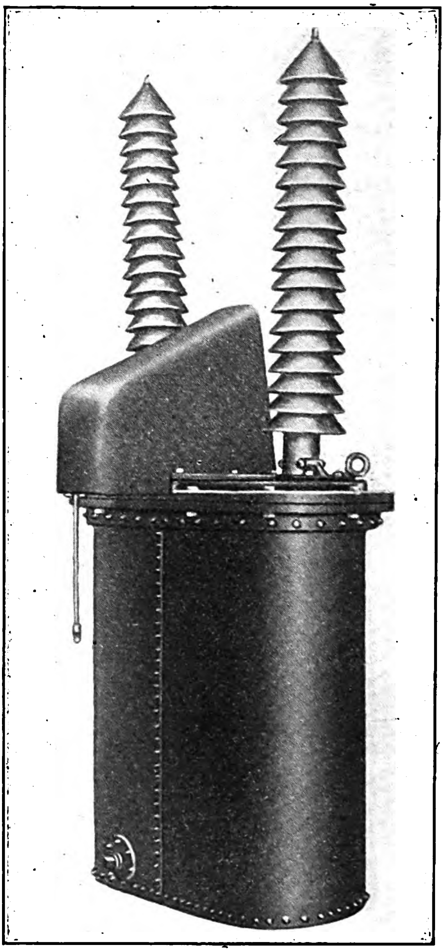

Fig. 8—Single-pole, 60,000-volt, 300-ampere, outdoor breaker. (This is one pole of three-pole indoor breaker, Fig. 7, arranged for outdoor service)

Service. For outdoor transformers the same care is required as for indoor transformers. An occasional test of the oil as obtained from the sampling pet-cock should be made. If attendance is at hand the usual load and temperature log should be kept. This applies to self-cooled and water-cooled units just as in indoor practice. Thorough and detailed inspections should be made at such infrequent intervals as the operating conditions would indicate to be desirable.

In the summer, protection from the sun will probably be an advantage, and this may take the form of a simple fence high enough and so placed as to cast a shadow over the transformer during the hottest hours of the day. At night the cooling conditions will be much more favorable, and the heat accumulated during the day will be discharged, so that each day is started with a cool transformer. The large amount of oil in self-cooled transformers represents a great thermal capacity; it acts as a sort of flywheel for the system, tending to smooth out temperature fluctuations.

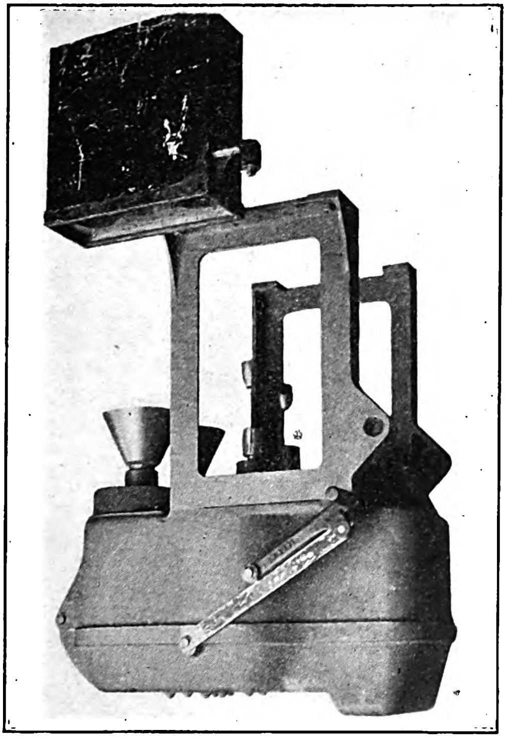

FIG. 9—11,000-volt, 300-ampere, remote-control, automatic, outdoor circuit-breaker

Water-cooled units do not require shade, and if attendance is at hand their temperature can be held practically constant under varying load and weather conditions, if desired, even without automatic thermostatic control of the cooling water.

In extreme winter weather, if the transformer is likely to be shut down for a considerable time the cooling coils should be freed of water so that they cannot freeze and burst.

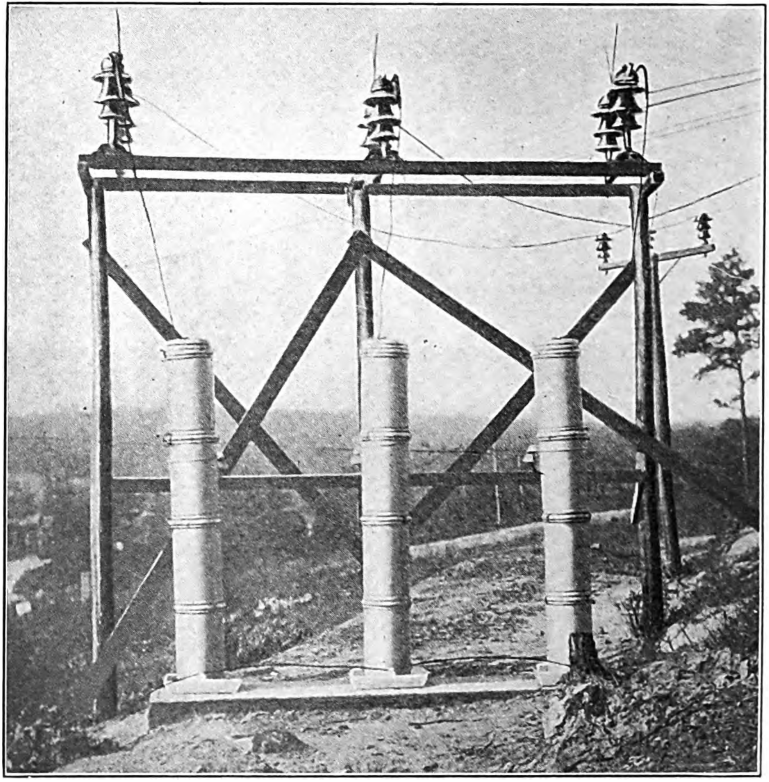

FIG. 10—Outdoor installation of 50,000-volt, electrolytic lightning-arresters

Transformer oil will thicken at about 0° cent., but does not harden so as to damage windings or case, as freezing water might do. When this cold the insulating quality of the oil is reduced, but not so as to make it unfit for its purpose. In ordinary service such conditions need not arise, as the iron loss alone will usually suffice to keep the oil fluid. In extreme weather conditions, self-cooled units may be kept warm by screening with a tarpaulin, thus reducing the effectiveness of the cooling surface. Similarly, the water-cooled unit may be operated without water, or with very little, to accomplish the same results. In some instances it may be found desirable to lag the water supply pipes during cold weather.

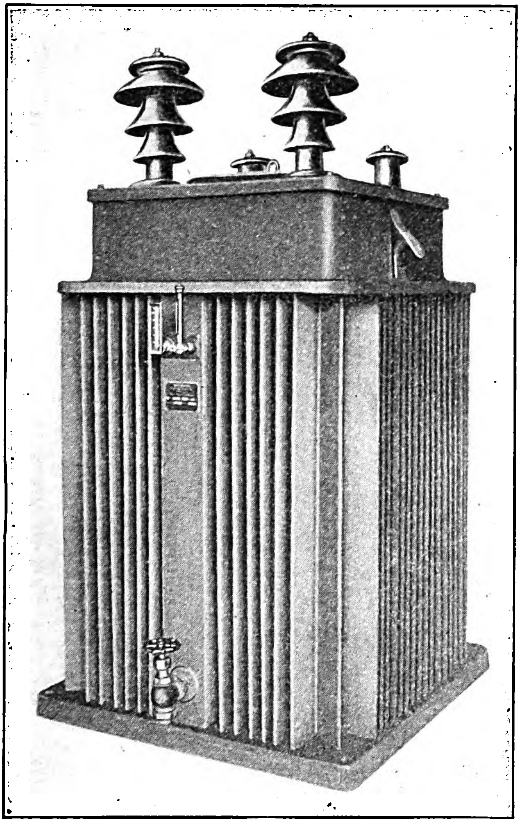

FIG. 11—300-kilovolt-ampere, 33,000/6600-volt, 60-cycle, oil-insulated, self-cooled transformer. (Illustrates general construction for outdoor transformers of moderate capacity)

A self-contained sub-station made up of transformers, circuit-breakers, and choke-coils has been proposed. Such an arrangement, if three-phase, would require but three high-tension leads and would dispose of twelve other leads otherwise required by switches and the choke-coils. If the choke-coils were omitted, six leads are still saved. For capacities up to approximately 250 kilovolt amperes this arrangement may be found attractive. Such units should be protected by fuses or other circuit-interrupting devices on the high-tension side, as a failure outside of the switch could not be relieved by it. Disconnecting switches should also be used.

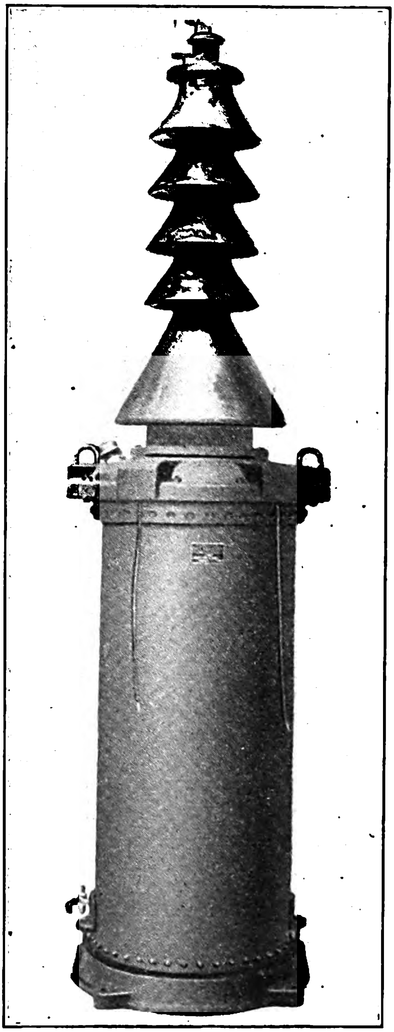

Fig. 12—60,000-volt, outdoor series transformer. (Fig. 1 shows two of these transformers installed)

A construction which permits of shipment in the case with oil is an improvement in transformer design which has been received with quite general favor, as the installation problem is much simplified. The usual unpacking, reassembling, and drying out, if necessary, is reduced simply to removing the blind flanges from the terminal openings and replacing the terminals in order to be ready for operation. Transformers arranged for shipment in their cases with oil, if made weatherproof, need never enter a building after leaving the factory, unless repairs or inspection should demand it.

Summary. The advantage of outdoor apparatus lies in cheapening the installation due to a saving in building; there is also less life and property hazard. The disadvantages are absence of protection from weather when inspecting, overhauling or making repairs, and exposure to molestors. The problem, as a whole, was, first the transformer; second, the switch; and, third, the protective apparatus. All of these have been worked out and some experience obtained. The problem now is to decide when outdoor apparatus is warranted. This is a question of the station rather than the apparatus, and is subject to the individual conditions of each case.

DISCUSSION ON "CONDITIONS AFFECTING STABILITY IN ELECTRIC LIGHTING CIRCUITS." NEW YORK, JANUARY 8, 1909

(Subject to final revision for the Transactions.)

Elihu Thomson: The paper I have to present is in large measure incomplete. It is merely a sketch or outline, and much of it is historical, going back to the early days of the inception of the art which this Institute represents. It was thought it would be well to bring together in one paper and place upon the records of the Institute some of the historical facts connected with the subject treated in the paper.

President Ferguson: The Institute is especially fortunate in having been able to induce so distinguished a member as Professor Elihu Thomson to present this paper to you this evening. There is probably no man in this country who is able to talk more authoritatively on this subject, or who has done more in the development of electric street lighting, than the author of this paper. The work which he did was in the early days, when electrical engineering was comparatively unknown, at a time when it required not only skill but courage and patience to accomplish results. I have the distinguished honor, gentlemen, not to introduce to you, but to call upon Professor Elihu Thomson, who will present a paper on "Conditions Affecting Stability in Electric Lighting Circuits."

A. E. Kennelly (by letter): Professor Thomson's interesting paper discusses a subject which has not received from engineers the attention it deserves; namely, the automatic maintenance of current stability in circuits which contain collapsible resistances; that is, resistances which tend to diminish with current flow.

Two principal automatic methods are discussed: namely, ballasting the circuit with extra impedances, and providing the generator with a drooping external characteristic.

The first method is especially applicable to constant-potential circuits. Its weak point is its wastefulness of power.

The second method is especially applicable to constant-current circuits.

The arithmetical relations that determine the restoration of stability to such a circuit are simple enough, if we regard the matter merely from the standpoint of static equilibrium; but in practice the problem is complicated by kinetic actions, such as the time-interval of arc-mechanism response, the time-interval of engine-governor response, the time-interval of field-magnet response, and other time-intervals alluded to in the paper. Consequently, the complete practical problem, as presented in a series-arc circuit, is arithmetically very complex, even with the accumulated experience of 30 years. It must have appeared yet more intricate in the early years of arc lighting.

It is very interesting to learn that a supersensitive arc-lamp mechanism in the series-arc circuit was found sufficiently effective as a stability regulator to make its practical adoption, in the early days, worthy of consideration.

The remarkable degree of current-stability in series-arc circuits supplied through constant-current or tub-transformers, which is familiar to all who have operated such circuits, is clearly explained in the paper. The external electromotive force characteristic shown in Fig. 4 would fall much too precipitately for effective use in a generator, as may be seen by comparing it with curve *B* in Fig. 3. The current stability in the case of the tub-transformer is only rendered possible, with the vertical drop of voltage characteristic in Fig. 4, by the automatic balancing of gravitational force against electromagnetic repulsion in the manner well known.

It is a curious fact that the property of diminution in resistance with current which may bring about current instability in an arc circuit, is the property which is utilized in wireless telephony to throw a vertical conductor into sustained electric oscillation, by means of voltaic arcs shunted by condensers.

Alex Dow (by letter): It is well known that any cause which disturbs the circuit voltage is productive of results which may be classed as instability and, conversely, that circuit conditions of apparently minor importance may be effective in maintaining stability. For instance, a constant-current Brush machine on a Mississippi River steamer was used to operate two 20-ampere, 50-volt arcs in series during the loading and unloading of the steamer, and, when the steamer was under way, to operate a 40-ampere, 50-volt searchlight. The field windings of the machine operated in straight series on the former service, and in multiple-series for the latter service; so that the field ampere-turns were constant and the armature ampere-turns were double when the searchlight was operated. The latter condition should have tended to produce stability. Nevertheless the two arcs in series were beautifully steady, while the single searchlight behaved sinfully. The completely successful remedy applied was the insertion of inductance in the searchlight circuit, in the form of some large iron wire wrapped over asbestos paper on a gas pipe core, in which gas pipe core sundry pieces of old iron found on the steamer were inserted to make the final adjustment.

Another instance. Two new circuits of *M* and *K* lamps in which the arc-length was controlled by a shunt around the arc, were unsteady when operated from their proper Thomson-Houston spherical armature machines. They were entirely steady when operated from Brush machines, and the Brush differential lamps were entirely steady when operated from the Thomson-Houston machines. Consequently, this exchange was adopted as the regular rule of operation. Subsequently it was found that if one-quarter to one-third of the lamps on the circuit were of the Brush differential type, the circuit would be steady on either machine.

In my experience the worst case of circuit instability was that of several circuits each intended to carry 150 arcs. They behaved very badly, and it was necessary to adopt a quick and a cheap remedy. The generators had not the drooping characteristic. Their short-circuit current was about twice the normal current. But they had an exceedingly effective regulator which would control closely the current supplied to a circuit naturally stable. The constructing engineer had combined those machines with shunt-wound arc lamps, not the lamps usually operated in conjunction with the generators. Each string of 150 lamps was served by rubber-insulated, lead-covered underground cables of high insulation resistance, high static capacity, and inadequate resistance to puncture. The capstone, so to speak, of the combination was that the lead cover of each length of cable was intentionally kept out of contact or connection with the lead covering of the succeeding lengths and was, because of frozen soil, virtually insulated from earth.

When these 150-light circuits were operating, all the telephones on the west side of that large city went out of business. One hundred modern wireless installations could not have been more effective in disturbing the ether. But the circuits would not stay in operation. The machines spilled, the cables punctured, and the arc-lamp posts burned out. The remedies applied were, first, the earthing of each section of lead sheath; secondly, a rearrangement of the circuits so that some old differential lamps were included in each string of shunt-wound lamps; thirdly, the steadying of the machines by various devices known in the art; and finally the substituting of different machines with marked drooping characteristics for the original efficient but very sensitive generators. The last remedy was, of course, final, but the effect of the connection of a comparatively few differential lamps was surprising.

E. W. Rice, Jr.: This subject is of great interest to me, because I had the rare privilege of association with Professor Thomson in the early days of which he speaks. I still have vivid recollections of the difficulties surrounding the design and manufacture of electric generators that would satisfactorily operate a load of the inherent instability possessed by the electric arc. It is easy for us with our present-day knowledge to discover the cause of those early difficulties. I doubt if the younger generation of electrical engineers can form a proper mental picture of the conditions surrounding the work of the pioneers in electric arc lighting. In those days practically no electrical measuring instruments were to be had; it was years before the ammeter, voltmeter, and wattmeter were invented. Besides this, the confidence of financiers in electrical inventions was not particularly great, and cash was notably scarce.

Without seeming to depreciate to the slightest extent the achievements of other workers of that period, I believe I am merely stating a historical fact in saying that the author of this paper had, of all his contemporaries, the clearest view and the strongest mental grasp of the electrical problems then pressing for solution. For some reason, probably because of his characteristic modesty, Professor Thomson has failed to call attention to the fact that the first scientific investigation of the properties of the electric arc were made by him with, I believe, the assistance of Professor Houston some time in 1878 or 1879, and that a paper setting forth the result of the investigation was published in the *Franklin Institute Journal* at the time. This paper clearly sets forth, among other interesting facts, the laws governing the variation of the resistance of the electric arc as an inverse function of the current, from which the inherent instability naturally follows.

I am also able to say that as far back as 1880, when I first became professionally associated with Professor Thomson, he frequently explained to me, in much the same language as that employed in the paper he has just read, the characteristics necessary for dynamo successfully to operate a circuit of arc lights. However, for the reasons that he has explained, it was not always possible to realize these views in practice. I remember we often wished that an arc lamp would behave like a respectable dead resistance.

It is interesting to note that the early machines operating but a single arc lamp undoubtedly owed a large portion of their success to the high internal resistance which improved the stability factor, and that the problem, as usual, became more severe when an attempt was made to improve the efficiency. Unfortunately, it seems to be a general law of nature that the highest efficiency is liable to be associated with the greatest instability. However, it is worth while to try for efficiency, as in the long run the most efficient system, if practicable, will survive, as instanced in the relatively short vogue of the inefficient so-called " short-arc " system described in the paper.

Referring again to the earlier one-light machines which were operated at widely different currents, I think this variation was probably partly due to the fact that stability was not always found at the designed current, and machines being small and of relatively large radiating surface could be operated at that current which gave stability without serious overheating. Professor Thomson's description of the early machine which operated satisfactorily only when artificial stability was produced by means of a single supersensitive arc lamp, and his suggestion that it might be desirable in practice to place such a lamp shut up in an iron box as a permanent part of the circuit, recalls to my mind that at a considerably later date I actually made use of this early experiment. My application of this device was made at a time when I was placed in charge of an exhibition of arc lights which was made by the Thomson-Houston company, in Boston, some time in the year 1882. For some reason the particular machine was unstable. After trying various expedients, I concluded that our exhibition was doomed to failure unless some immediate remedy were applied. As it was impossible to make any general changes in the machine or arc lamps, I arranged one of the lamps as a supersensitive stability regulator, and kept it operating in part of the space where it would be unobserved by the public. The remaining lamps were, as I remember, entirely satisfactory. After the exhibition the machine was properly tinkered until it worked in a satisfactory manner.

Professor Thomson mentions one method of improving the stability, or even creating stability, in a machine of unstable characteristics, which consisted in establishing a "short-circuit band of copper wire around the field cores parallel to the winding." I remember this device as a sort of powerful medicine that could be used successfully only in small doses. It, of course, had the objection mentioned by Professor Thomson, of increasing the amount of required copper, but I remember it also had the added objection that if the short-circuit band were made of too large cross-section, so as to become a fairly good secondary circuit, the machine had the characteristics of a separately-excited machine. Under such conditions any flashing of the commutator was enormously increased in intensity and prolonged in time; so great was this fault that for this reason alone the machine would become uncommercial. On one occasion one of these machines gave so much trouble that I was sent to investigate its cause. I found the machine, of 10-light capacity, entirely stable and satisfactory so long as flashing was prevented; but if for any cause a flash occurred at the commutator, the flash would continue for so long a time as actually to extinguish the arcs, seriously interrupt the service, and exhaust the patience of the mill owner. The machine had to be replaced. After the short-circuit band was reduced to proper proportions the same machine was found to operate in an entirely satisfactory manner.

It is pleasing to note the valuable and timely suggestion made in the closing paragraphs of the paper, which point out the possibility of increasing the efficiency of the already extremely efficient flaming arc lamp, by employing methods to maintain stability with minimum loss.

Dugald C. Jackson: When I was at Cornell University, the laboratories possessed one of the old Wallace arc lamps with plate electrodes made of gas-house carbon. The arc formed between adjacent edges of these plates was prodigious, and absorbed a corresponding volume of current. It wandered from right to left and from left to right at will, along electrode edges perhaps a foot long. It was sometimes here and sometimes there, at its own volition, and the illumination afforded was too erratic to be useful.

Arc lighting with cylindrical carbons ⅝-in. or less in diameter had even then come to stay; but there was a contest on between the short or hissing arc of approximately 20 amperes and perhaps 35 volts, and the long or silent arc of approximately 10 amperes and perhaps 50 volts. Each had its ardent supporters. But the hissing, flickering, short arc returned so much less light per unit of energy supplied to it that its commercial life was doomed, notwithstanding the good workmanship, for that day, in the Weston shunt-wound dynamos, and the gems of mechanicians' skill comprised in the Weston lamps, which among some others, supported the short-arc or low-potential arc lighting system.

It required a bold and original man to stake out a feasible path into the domain of the unstable long or high-potential arc. But the talents of Mr. Brush and Professor Thomson, each in his own way, brought the desirable end. Mr. Brush's dynamo, judged by the dogmatic theory of that day, was viewed as a curiosity; Professor Thomson's dynamo was looked upon as a monstrosity and contrary to the proper theories of dynamo electric machines. But both dynamos abundantly proved their right to exist, and both proved the lack of imagination of their critics. The fault of the critics lay in trying to apply an incomplete theory of dynamo electric machines to one element (the dynamo) of a complete system comprising several elements, all of which react on each other in a complex manner. I think that even now the way is not generally understood in which the limited theory of dynamo electric machinery that is sufficiently comprehensive to explain the performance of constant-potential direct-current machines requires extension and generalization to apply suitably to series arc machines.

In viewing the magnetic flux entering the armature of a direct-current constant-potential machine, we think of the aggregate flux as a determining feature of construction and operation. In the case of alternating-current machines, we generalize further and recognize that the position of the flux with respect to polar faces and arrangement of the armature conductors affects the form of the pressure wave and the output and functioning of the machine. A like condition seems to be even more marked in the case of the Brush arc light machine, and *the positioning of the flux* which enters the armature core may be of an importance comparable to the importance of the aggregate strength of field. For example, I have understood that in some Brush machines changing the polar tips from soft steel to cast iron has actually increased the capacity of the machines. These are machines in which, of course, armature coils are changed from series to parallel relations, and the reverse, by the action of the commutator in each revolution of the armature. A rational theory includes such effects; and its guiding finger points to such improvements as the reduction of copper required per kilowatt of capacity referred to in the paper, By " positioning " of the flux, I mean the distribution as it enters the armature core, say at full load, and the variation of the distribution with changing current.

My first intimate acquaintance with the Thomson-Houston arc light machine was made with a 30-light machine in the later 80's in the middle of the Mississippi valley at a place where repair parts were unknown. A sleepy attendant allowed the lubrication of the blower to become defective, the runner stuck in the case, and the blower case was torn from its bolts and entangled with a mess of wreckage of the links and levers of the regulator mechanism. The accident was no fault of the machine itself. To show the essential simplicity of the type, I will say that new bolts and some links and levers roughly shaped from iron rods by the aid of a country blacksmith's forge put the machine in satisfactory and prompt commission, and it was continuously used while new parts of orthodox construction were being obtained from the factory in the East.

My observation of that machine, and many others of the same or of larger size, has led me to view the function of the blower a little differently from the manner stated in the paper. I differ with Professor Thomson, but the difference may, after all, be only a matter of definition. A close observation of the working of a Thomson-Houston arc machine shows an obvious blowing out of the arc. The blowing out is not like that of a candle, where the flame is blown from the wick by a blast; but the air blast crosses the path of an arc existing between commutator segments, stretches it to the point of rupture, and replaces the heated gases by air which is cool and unpolarized (Professor Thomson prefers the word unionized) and therefore will not support a renewal of the arc until it is re-established by the action of the brushes. A similar effect may be produced by blowing a brisk blast across the arc of an arc lamp.

The constant-current transformer, associated with alternating-current lamps, referred to in the paper, brought arc lighting within the scope of economical central station practice, since it made the operation of arc lighting from current generated by great generating units an assured fact. The addition of the mercury-arc rectifier has done much to extend this improvement, but it is apparent that the end is not yet. Indeed, improvement must be vigorously prosecuted if electric arc lighting is to maintain a satisfactory margin of supremacy over the new gas-burners for outdoor lighting.

C. M. Green: The early observation of armature reaction is, in my opinion, the basis of all of our arc machines of to-day. Under full-load conditions the point of commutation is under the following pole piece, and as the load is decreased, or lamps are cut off, the point of commutation goes still farther under the following pole piece. The regulation of various machines is accomplished in various ways. In the Thomson-Houston and Fort Wayne machines the final adjustment or regulation is accomplished by means of varying the armature reactions—by overlapping the double brushes in the Thomson-Houston machine; by short-circuiting the armature during part of the revolution and separating the double brushes in the Fort Wayne machine. In other words, in the Fort Wayne machine with constant current through the field there are less active conductors in the armature under full load than under no load. The regulation in the Brush, Schuyler, and Excelsior machines was accomplished by varying the field strength—in the Brush and Schuyler machines by shunting more or less current through a rheostat and in the Excelsior machine by varying the number of turns on the field.

The short-circuit bands around the fields common to both the Thomson-Houston and early Brush machines undoubtedly had a very beneficial effect. We have found other ways of obtaining stable operation as may be seen from the following:

Brush arc generators			
No. of machine or class	7.5	12	13
Volts rating	2500	8500	15000
Amperes	9.6	6.6	4
No. of commutator	3	4	4
Volts per commtuator section	833	2125	3750
Temperature rise of pole shoe above air for	270° cent	11° cent	30° cent
Material of pole shoe	Cast iron	Laminated	Cast iron
Closed copper band on fields	Yes	No	No
Pounds of copper per kw. output	53.7	29.5	26.2
Efficiency full load	70.5	88.0	85.4

For stability of operation of machines on an arc-lamp load, one of the most essential features is the saturation of the iron. An examination of Fig. 3, curve *C*, shows that there is very little saturation until the curve drops very abruptly. At this point the armature bobbins are commutating under the following pole tip, and the pole shoe becomes very highly saturated just beyond the magnet core. Into some 0.5 in. holes bored in some of the shoes I inserted a thin steel rule; the rule was attracted very strongly to the iron, showing a heavy magnetic field across the hole. The magnetism held the rule so tightly that it could be twisted about 30° in 3-in. lengths. I doubt if there are any machines manufactured to-day in which the saturation of the iron is higher than in the Brush machine.

I desire to add another characteristic curve to the two which are given in Professor Thomson's paper, Fig. 2 and Fig. 3. One showing the effect or characteristic of varying the length of spark on the commutator, entitled "External Characteristic No. 11 Brush Arc Generator." When the generator is running on short-circuit, if the spark length be increased, the current rises, this however, continues to a less and less degree, as the full arc-lamp load of the machine is approached. At the point of about maximum output a variation in the length of spark has very little if any effect upon the current output of the machine. If the machine is still further loaded, the brushes move backward, and if the spark is lengthened out the current falls off rapidly; in other words, a short distance beyond the point at which changing the length of spark does not affect the output of the generator, is the maximum load of arc lamps which the machine will carry. In addition to this, it is the maximum output which can be obtained from the machine. Either short-circuits or open-circuits will decrease the load and the power required to drive the machine. Generally speaking, arc machines do not operate well at reduced current, and the kilowatt capacity is practically in proportion to the square of the current, and the operation is poor due to the fact that the iron is not saturated at lower current.

The first 120-light 6.6-ampere Brush arc generator was developed in Lynn, worked satisfactorily, and was sold to the Boston Electric Light Co. Shortly after that they installed 18 more machines. When about one-half of them were delivered I was told that they were unsatisfactory. The difficulty in the machines was corrected after extensive tests by changing the material in the pole shoes from steel casting to cast iron, taking 360 lb. of copper from the fields, rewinding the rheostats, and increasing the rating from 8000 to 8500 volts.

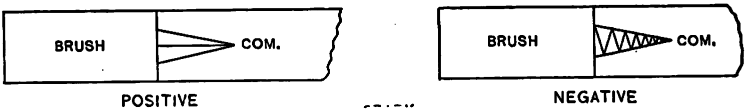

FIG. 1

Later additional changes were made, reducing the amount of copper in the original machine by 636 lb. or more than 25 per cent.

Experiments were conducted at Cleveland and approximately 500 lb. of copper were taken from the fields and the magnet cores increased from 5.25 in. to 6 in. in diameter. The generator operated satisfactorily on a resistance load, but when the machines were operated on an arc lamp load they were not satisfactory. They would run satisfactorily to about 5000 volts, but not to 6250 volts, their rated load. Characteristic curves were taken up to about 5000 volts and were satisfactory for the operation of arc lamps, but when the field strength was increased to obtain a higher voltage the peak of the characteristic curve went out to 12 or 13 amperes. Arc lamps could be operated at this current, but it was not what the customer wanted.

About two years later further experiments were carried on, and we succeeded in reducing the copper on the fields 636 lb. and the machines worked satisfactorily.

No doubt but that the Brush arc is a pole-shoe machine. For example, I thought we could reduce the magnetic leakage in the machine and increase the output by removing the sharp corner from the back of ends the pole shoes by making the radius of the curve about 0.25 in., but the output was reduced 5 per cent or 300 volts. I also conducted further experiments, displacing the pole shoes somewhat, about 2 in., from the center of the magnet cores. I found on these machines that a change in the direction of rotation would give an output of four to one, depending upon whether the long end of the pole shoe was leading or trailing. With the long end in leading position, the machine gave the larger or maximum output. The commutation, however, was not satisfactory over the necessary range. Another peculiar thing in arc generators is that the brushes move backward with increasing load, which is apparently the reverse of constant-potential machines; but in both machines the brushes move forward when the resistance in the load circuit is reduced.

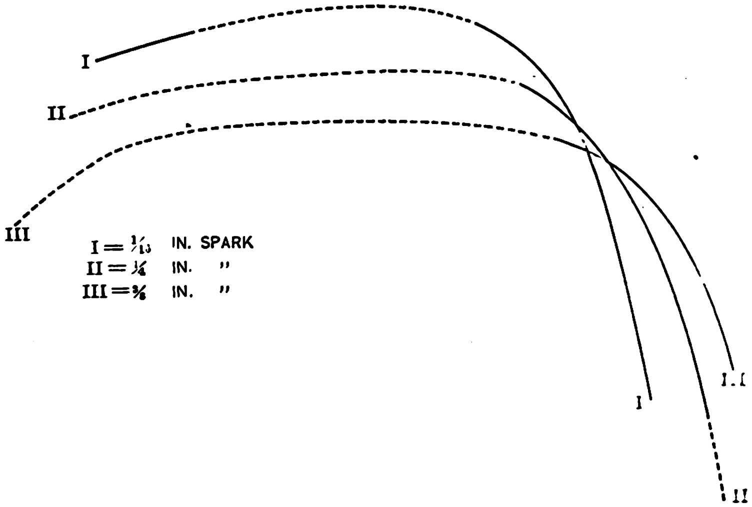

FIG. 2

The Brush and also the Thomson-Houston arc generators possess the peculiar property of allowing us to change the direction of the rotation of the armature, keeping the direction of the current through the field the same and maintaining the same relative position for the positive and negative brushes on the commutator. This seems wrong, but theoretically it is right.

The instantaneous fluctuations in current of the Brush arc generators amount to about half a per cent. I do not know exactly what it is with the Thomson-Houston machine, but I know it is many times greater. The steadying effect and alternating voltage across the fields of Brush machine are negligible. In the Thomson-Houston machine the steadying effect I believe to be very appreciable and essential, and if my recollection is aright, the alternating voltage across the field amounts to about 75 per cent of the rated direct voltage. This varies somewhat under different conditions of load.

I think the Brush multicircuit arc machine has interfered more with telephone service and done more to improve it than any other machine, by forcing the telephone companies to put in metallic circuits. We have also experienced trouble in operating these machines on underground cables. I should like to bring to the notice of the Institute the use of a transformer on a fluctuating direct Brush circuit for the purpose of preventing surges between the generator and the circuits, which tend to puncture the insulation on the cables but as yet have had no effect so far as I have been able to find out on the generator. This seems strange when a rated 8500-volt machine usually breaks down on about 10,000 volts alternating current, jumping from the armature bobbins to the pole pieces.

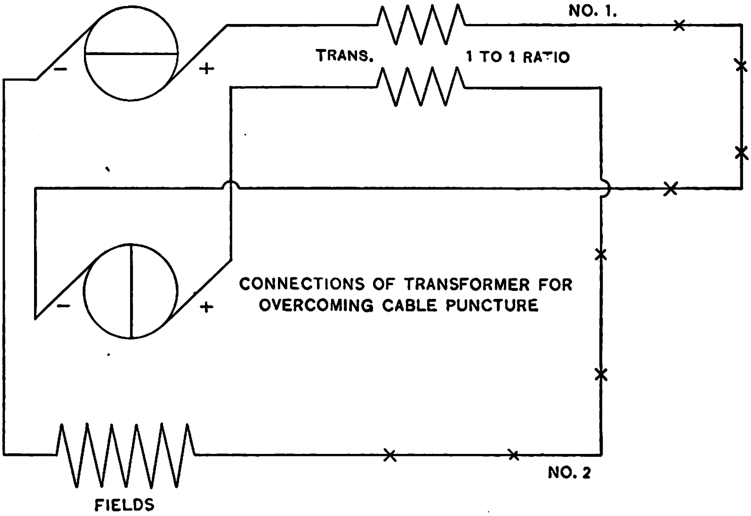

FIG. 3

The transformer is so connected that the currents through the windings neutralize each other. If we put capacity in the circuits, with the varying voltage which is generated between different commutator sections, we will have an extra current flowing through the transformer due to the capacity, and this will transfer part of the high electromotive force from one loop or section of the generator circuit over to the other so that there will be very little alternating voltage between the negative brush in the figure and that end of the transformer winding connected to load in series. On the 12 Brush arc generator rated at 8500 volts, 6.6 amperes, two-circuit machine, the alternating voltage across the transformer is about 800 at full load. The larger the amount of capacity or length of underground cables in the circuit, the greater the alternating voltage across the transformer, so that we will have changed from an unstable to a stable condition by the use of the transformer, and the electrical surges in the circuit, which punctured the cables are cut out, but they had no effect so far as we could observe upon the machines or upon the lamps.

The disturbances on the telephone lines, either grounded or common metallic return, were due to the electrostatic effect, or to the wave of voltage which continually traveled along the lighting circuit. They were not due to the current or magnetic induction effect, which was proved by the fact that telephone disturbances were experienced on multicircuit machines when one of the circuits was short-circuited so that there was no current flowing in it, only the variation in potential existing. The difficulty was overcome by the telephone companies putting in metallic circuits which should have been done long before, as the service at that time was unsatisfactory, due to stray currents from electric railway and other circuits.

John B. Taylor: Mr. Green has just referred to fluctuation or pulsation in value of the current, or more properly (since we may have pulsations of widely different frequencies due to various causes) the extent to which the direct-current arc circuit becomes an alternating-current circuit with frequency determined by a number of points of commutation. At first sight, an armature with a three-part commutator might be expected to introduce a considerable alternating-current component, but a rough analysis will show that this alternating component is not very great, and there is also the reactance of the circuit and apparatus tending to smooth out the alternations. A neighboring telephone circuit, however, as already pointed out, gives evidence of the alternating feature, and in addition I was surprised to find a perceptible alternation in illumination.

This I noticed about eight years ago while making some stroboscopic tests on alternating-current motors by the aid of a striped cardboard disc rotating, and illuminated by an alternating-current arc. About the same time some old Thomson-Houston direct-current open arcs were being replaced by 60-cycle enclosed arcs supplied from constant-current transformers; during the process of changing, both systems were in operation at the same time. I rotated the disc on one street corner near a 60-cycle arc for the edification of a friend, and on the next corner advised that no such stroboscopic effect would be apparent on account of the direct-current arc. I was surprised, however, to find that there was a decided alternation in intensity of illumination as evidenced by the disc appearing stationary at the proper speed, although, of course, the contrast between light and dark stripes was not so definitely marked as with the 60-cycle lamp.

I wish to ask if tests have been made which can be quoted to show how much alternating effect there is in the Thomson-Houston circuit with the machine under average load, and if these alternations are sufficient appreciably to affect figures for efficiency for such machines where the output has been measured by voltmeter and ammeter of the D'Arsonval or Weston type. Such meters give the mean value of current and voltage rather than the root mean square value, and in the extreme case of a rectified sine wave, ammeter and voltmeter individually indicate but approximately 0.9 of the proper value, while output in watts, as determined by their product, would show a little more than 0.8 of the true value. If this has not been taken into account, some values of efficiency on such generators might properly be increased by a small value, possibly 1 or 2 per cent.

There is one feature of stability rather outside of the scope of this paper; that is, the stability of illumination as distinguished from stability of current producing the illumination. Incandescent lamps are probably the most stable form of artificial illumination which we have, while the illumination from an arc, in spite of cored-carbon and such devices, still leaves much to be desired.

As Dr. Kennelly has pointed out in his letter, the inherently unstable feature of the arc itself is now being turned to good use in wireless telegraph and telephone service.

I believe that Professor Thomson, as usual, has anticipated many other experimentors in this direction and I hope he can tell us something of his early experiments with the "singing" or high-frequency arc. It seems possible that we may have in some of the underground cable distribution systems for arc lighting, a condition not unlike that which is purposely arranged for the singing or oscillating arc; that is, a capacity (made up of cable) around the arc in series with more or less reactance (principally in the lamp mechanism). If both reactance and capacity should chance to have the proper values, and the resistance and other losses were not too great, this combination might build up sufficient voltage to account for some unexplained cases of breakdown on such systems.

H. G. Stott: I would call attention to a very important historical note in the paper, where reference is made to one of the first series arc dynamos. It is as follows:

> The first series arc machine designed and built under his supervision was also the first dynamo having the three-coil (star three phase) winding with three segment cummutator.

I believe Professor Thomson can enlighten us very considerably on the point, which was recognized by him and his associates, that this was a three-phase machine, and that power could be transmitted from it and supplied to another machine by putting on what was then called slip rings. I think from an historical point of view, it would be interesting for Professor Thomson to bring this out when he closes the discussion.

Elihu Thomson: Reference has been made to the use of a partial load of differential lamps. I remember that this was resorted to as a steadying influence, in times when unstable circuits were found. It was also noticed that with an increase in line-length on some of the early Thomson-Houston arc machines, the machine would carry more load. A 50-light machine with a long line would often carry 55 arc lights. Undoubtedly in that machine the inductance of the field windings had a good deal to do with the operation of the machine, and this inductance was added to by a long line. It was a machine which when first sent abroad evoked the opinion that it ought not to work—but did work. One must take into account the fact that although at the commutator during regulation there was a definite short-circuit repeated six times during a revolution, the inductance of the windings kept the current from too great fluctuation.

Mr. Rice has adduced several interesting matters. I remember the instance he has told of in which he had to resort to the use of a sepersensitive arc to keep the current stable on the circuit. I also remember very well the condition he referred to in which we had too much of a copper band on the field; the field magnetism did not vary enough. It is well known that in the case of machines of the open-coil type, if the field is maintained and any flashing occurs, such flashing becomes permanent; they can not be used as separately-excited or even as shunt-excited machines.

Mr. Stott has asked about the original three-phase machine. When we first applied for a patent on the three-coil machine, it was illustrated in the patent specification with a commutator and also with slip-rings, as alternatives, as the novelty of the structure was well appreciated; but the patent office was unwilling to recognize our arguments with relation to the winding with slip-rings, and to save time we finally gave up and took out the patent with claims for the winding with commutator segments, and left out the slip-ring combination. As shown in the specification originally with slip-rings, it was, of course, an alternating three-phase machine. In 1881, in New Britain, we were experimenting with a machine which had slip-rings.

We had carried the terminals of the armature to three slip-rings, in addition to the commutator. The object was to control the sparking of the machine by putting condensers between the commutator segments, and to do that we carried slip-ring connections to condensers outside. We found that the trouble was that the condensers would not live, but go off in a flash. At the same time we noticed high-frequency effects with the condensers, getting sparks between turns of wire leading to the condensers instead of the current going round. The desirability of having another such machine with slip-rings was discussed, as we knew that then we could transmit power without commutation from one machine to the other machine; but as we were not doing power distribution at that time, and no transmissions were then contemplated, we put the matter aside.

In regard to Professor Jackson's statement with relation to the function of the blower, I quite agree with him that the blower would not work unless we have a spark to blow upon. We must have the terminal spark from the brush forward as the segment leaves the brush so as to be able to knock it out of the way with the air blast, and insert the cold air layer. The residual arc was deflected into a new position. The air blast acting synchronously with the motion of the segment, would drive the tapering end of the spark away down under the segments of the commutator air insulated as it was, thus allowing plenty of room to put in the cold air. We may perhaps account for the old anomalous so-called Ball unipolar machine by supposing that it was at first made with the four pole-pieces, and that the stability was not then what it should be. By taking off two of the four pole-pieces, thereby lessening the effect of the field, and increasing the armature reaction, stability was probably secured. It then became necessary to speed up the machine to obtain a fair output. The average arc dynamo speed at that time was something like 700 or 800 rev. per min., and this machine ran up to 1600 revolutions.

Mr. Green referred to the remarkable effect of rounding the corners of the pole-pieces in the Brush arc machine, thus adding evidence to show that it is properly characterized as a pole-piece machine. The question in regard to the fluctuations of current in the Thomson-Houston machine I have virtually answered by saying that the field coil circuit itself acts as a high inductance and tends to smooth out fluctuations. There would otherwise be a very ragged current curve. In fact an interrupted current would exist if it were not for the large inductance of the field coils. I may mention that when the closed copper band was put on the field, the current was considerably more fluctuating than when it was not used, as would naturally be expected. The current fluctuation was greater with partial load than with full load from the fact that during regulation there was a longer interval of short-circuiting with lighter loads.

Mr. Taylor mentioned stability of illumination. That is a little outside of the paper, and it would take some time to discuss it. I do not think we have time to consider the high frequency arc matter now, and its application to wireless telegraphy.

E. A. Sperry (by letter): I was so fortunate as to have been born almost under the eaves of Cornell and was a youth when our late lamented founder, Professor William A. Anthony, was in the midst of his early activities at that institution. It will be remembered that he was the first one to build a Gramme electrical generator in this country, the machine exhibited at the Centennial Exhibition in Philadelphia in 1876. I watched some of the construction of this machine with eager interest, as well as many of the experiments that were tried with it, and some of the overhauling in 1878. I feel that we never have accorded sufficient credit to Professor Anthony. He was a source of inspiration to a great many engineers of the present generation, combining as he did in a most extraordinary degree keen perception in theory as well as wonderful mechanical ability and unusual skill as a pure mechanician.

In 1879, I had built my first dynamo and arc lamp in Cortland, New York, near Ithaca. Then in Syracuse, I completed a 15-light machine which in 1880 was taken to Chicago, where we built a plant and started manufacturing a system of arc lighting, which included a regulator by means of which the lamps could be turned on and off. It was shown that a 20-lamp circuit could be cut down to five and later we found means for reducing a 30-light machine down to one lamp.

The early machines were all of the short-arc type. We started to build the long silent arc of about 9 amperes in 1884. As I remember one of the first 6-ampere machines was sent to Cornell for testing purposes. After we were established in Chicago, there came upon the horizon a new lamp, about which I had already quite thoroughly posted myself. The current was supplied by a Thomson-Houston arc-light machine. The first night the lamp started I was present as an observer. I thought at that time the lamp ought to work; there was a case, it seemed to me, of a pulsating current, in which the current supplying the lamp was forced along the line in impulses which were positively divorced from each other, and, through the vigorous shaking and vibration which the regulator of the arc was constantly undergoing, no wonder the lamp could operate well and feed continuously. With our finely divided commutator and smooth flowing current, however, it was not an easy matter to cause a continuous and uniform feed of the carbons. Before many years the Thomson-Houston system became formidable, and we found great difficulty in maintaining our standard in competition with it. This system was developed by Professor Thomson.

The tests at Cornell in 1885 showed us that the armature reaction and the drooping characteristic of the machine were the secrets of stability and regulation in our machines. But in those days it was a matter very largely of cut and try methods.

About that time I carefully constructed an ammeter and sent it to Charles F. Brush at Cleveland, asking him kindly to mark 9.6 amperes on the scale. Correct measuring instruments were difficult to obtain and even more difficult to keep in calibration.

A paper presented at a meeting of the Toronto Section of the American Institute of Electrical Engineers, Toronto, Ont. December 18, 1908.

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(*Subject to final revision for the Transactions.*)

NOTES ON THE COST OF POWER.*

BY H. G. STOTT.

In engineering estimates there is probably no item which contains so many variables as that representing the cost of power. Consequently we frequently find a wide divergence of opinion as to the results which may be expected under different conditions. In all types of plants the influence of investment upon the cost of power is one which is apt to be slighted in the estimates, and if not slighted it seems to be subject to more errors than any other factor which enters into this cost. This is particularly the case with hydraulic plants, as of necessity water storage, flumes, racks, tail-race, etc., enter into the estimate, with the result that the actual cost has sometimes been found to be 100 per cent greater than the estimated cost.

In the same way indeterminate items of cost, such as foundations, cost of labor, etc. enter into practically all the calculations, so that when we take into consideration the influence of location upon the cost of coal, labor and water, as well as upon the investment, it is readily seen that the actual cost of power is of necessity so variable as to make impossible anything like a standard cost per kilowatt-hour.

With the above limitations in mind, the following notes on the cost of power have been compiled with the idea that they might form a guide to show at least the fundamental relations between the various items going to make up the cost of power, and at the same time show what is actually being done to-day in large plants having a maximum load of over 30,000 kw.

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* The author wishes to acknowledge the work of Messrs. G. I. Rhodes and R. J. S. Pigott in calculating and plotting curves, and the kindness of the New York Edison Co. and Interborough Rapid Transit Co. in furnishing load-curves.

The following table has been taken from a paper* contributed by the author two years ago and has been expanded and revised so as to bring it up to the results now obtained in actual practice. The principal changes made have been due to the better economy obtained in the steam turbine, and in the reduction of the total fixed charges from 12 per cent to 11 per cent; fixed charges composed of 5 per cent interest, 1 per cent taxes and general administrative expenses, and 5 per cent for amortization or obsolescence in the steam and hydraulic plants.

RELATIVE COSTS PER KILOWATT-HOUR. DISTRIBUTION OF MAINTENANCE AND OPERATION

	Reciprocating steam plant	Steam turbine plant	Reciprocating engines and low-pressure steam turbines	Gas-engine plant	Gas engines and steam turbines	Hydraulic
MAINTENANCE						
1. Engine room, mechanical.......	2.59	0.51	1.55	5.18	2.84	0.51
2. Boiler or producer room........	4.65	4.33	3.55	1.16	1.97	....
3. Coal and ash-handling apparatus	0.58	0.54	0.44	0.29	0.29	....
4. Electrical apparatus...........	1.13	1.13	1.13	1.13	1.13	1.13
OPERATION						
5. Coal.........................	61.70	55.53	52.44	26.52	25.97	....
6. Water........................	7.20	0.65	0.61	3.60	2.16	....
7. Engine room, labor............	6.75	1.36	4.06	6.76	4.06	1.36
8. Boiler or producer room labor..	7.20	6.74	5.50	1.81	3.05	....
9. Coal and ash-handling labor....	2.28	2.13	1.75	1.14	1.14	....
10. Ash removal..................	1.07	0.95	0.81	0.54	0.54	....
11. Electrical labor..............	2.54	2.54	2.54	2.54	2.54	2.54
12. Engine room lubrication........	1.78	0.35	1.02	1.80	1.07	0.20
13. Engine room waste, etc........	0.30	0.30	0.30	0.30	0.30	0.20
14. Boiler room lubrication, etc....	0.17	0.17	0.17	0.17	0.17	....
Relative operating cost per cent....	100.00	77.23	75.87	52.94	47.23	5.94
Relative investment per cent.......	100.00	75.00	80.00	110.00	96.20	100.00
Probable average cost per kilowatt.	125.00	93.75	100.00	137.50	120.00	125.00
Probable fixed charges............	11%	11%	11%	12%	11.5%	11%

For steam-turbine plants larger than 60,000 kw. the cost per kilowatt may be reduced to $75.00.

In the other items will be found changes due to the reduced cost of steam turbines, and also due to the possibility of saving the water of condensation by separating out the oil between the reciprocating engine and the steam turbine. Under the

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* Power Plant Economics, by Henry G. Stott. Transactions A.I.E.E., 1906. Vol. xxv. pp. 1–27.

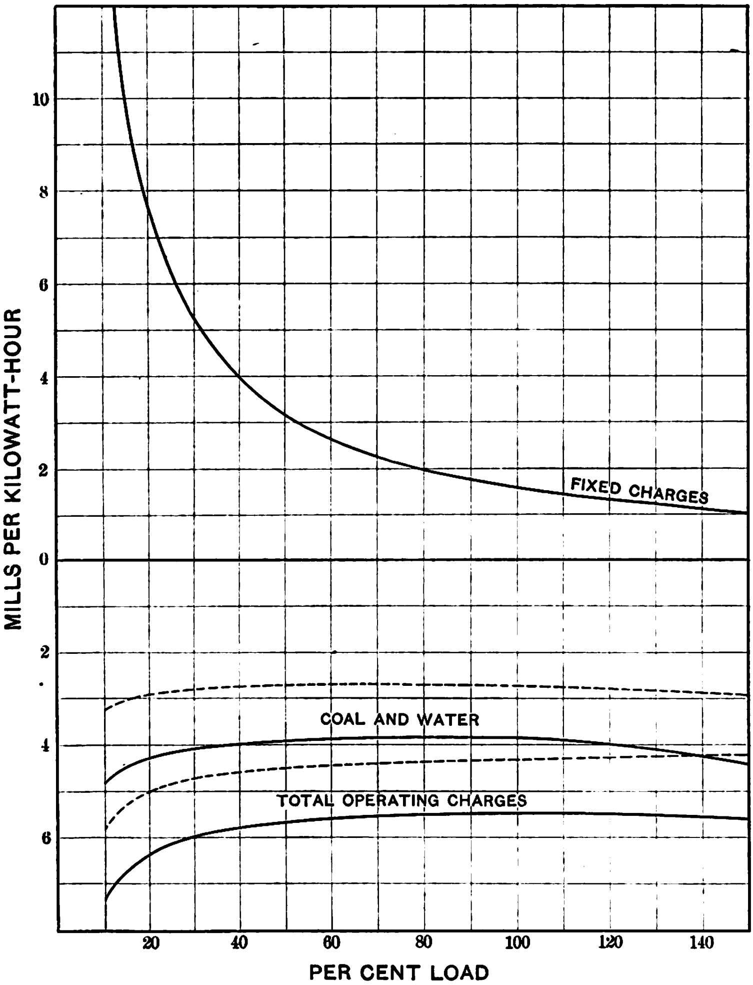

Fig. 1.—Cost of power. Reciprocating steam-plant.
Plant cost = $125 per kilowatt.
Interest, taxes, depreciation, etc. = 11%.
Solid lines = coal @ $3.00—14,500 B.t.u. per lb.
Dotted lines = coal @ $1.50—11,000 B.t.u. per lb.

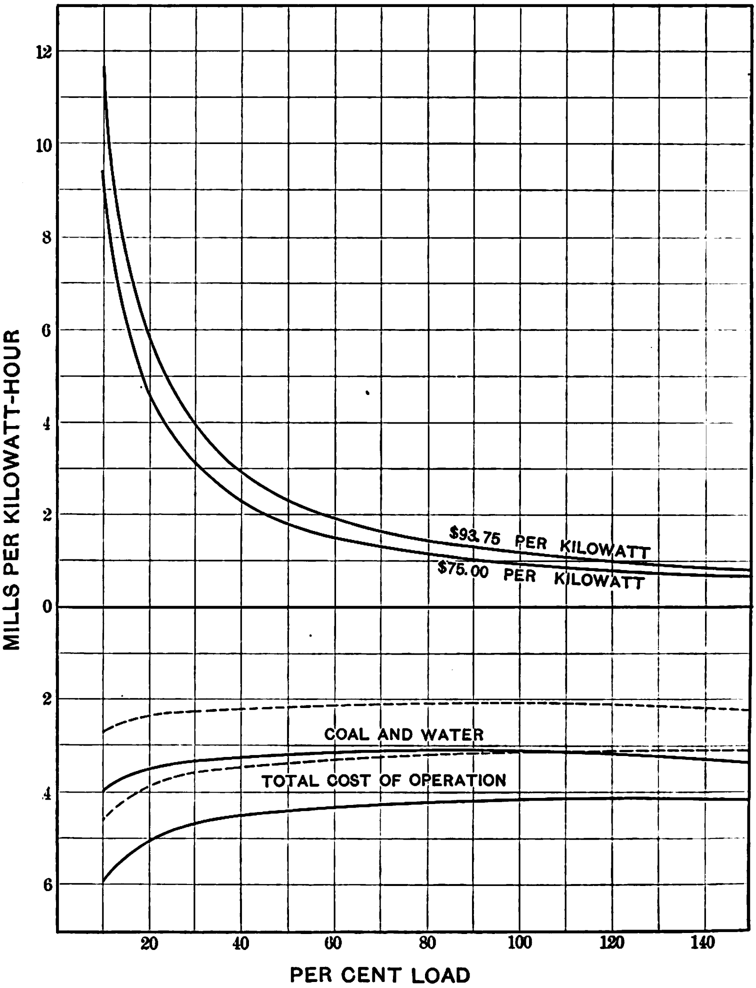

FIG. 2.—Cost of power. Steam-turbine plant.
Plant cost. = $93.75 per kilowatt —A.
Plant cost = $75.00 per kilowatt—B.
Interest, taxes, depreciation, etc. = 11%.
Solid lines = coal @ $3.00—14,500 B.t.u. per lb.
Dotted lines = .coal @ $1.50—11,000 B.t.u. per lb.

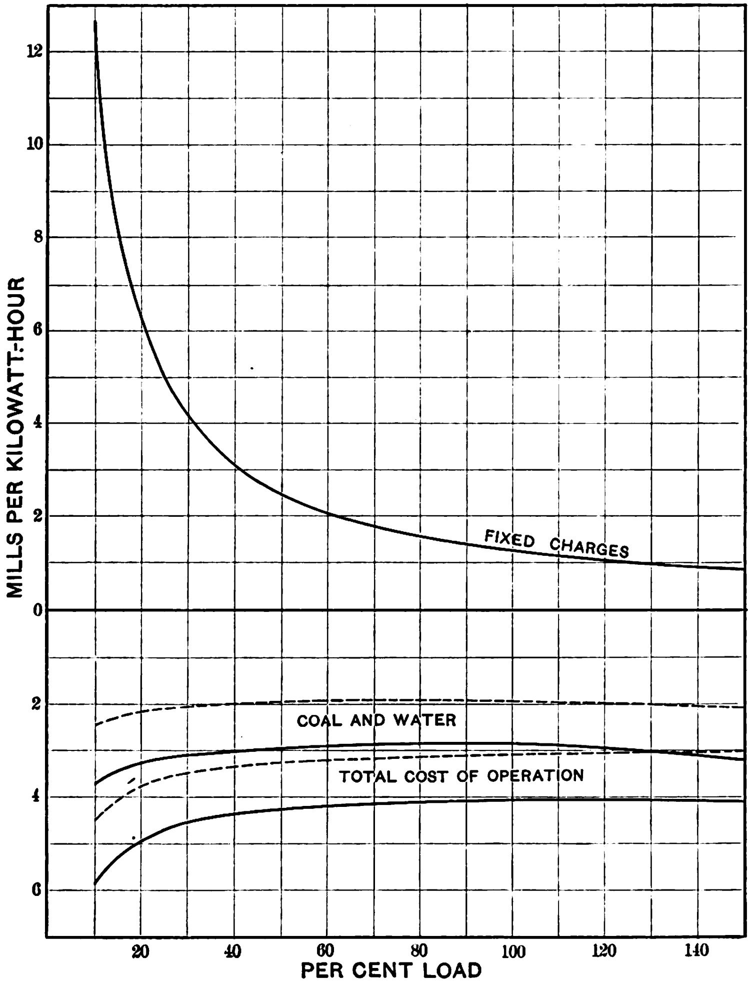

FIG. 3.—Cost of power. Reciprocating engine and low-pressure turbine plant.

Plant cost = $100 per kilowatt.
Interest, taxes, depreciation, etc. = 11%.
Solid lines = coal @ $3.00—14,500 B.t.u. per lb.
Dotted lines = coal @ $1.50—11,000 B.t.u. per lb.

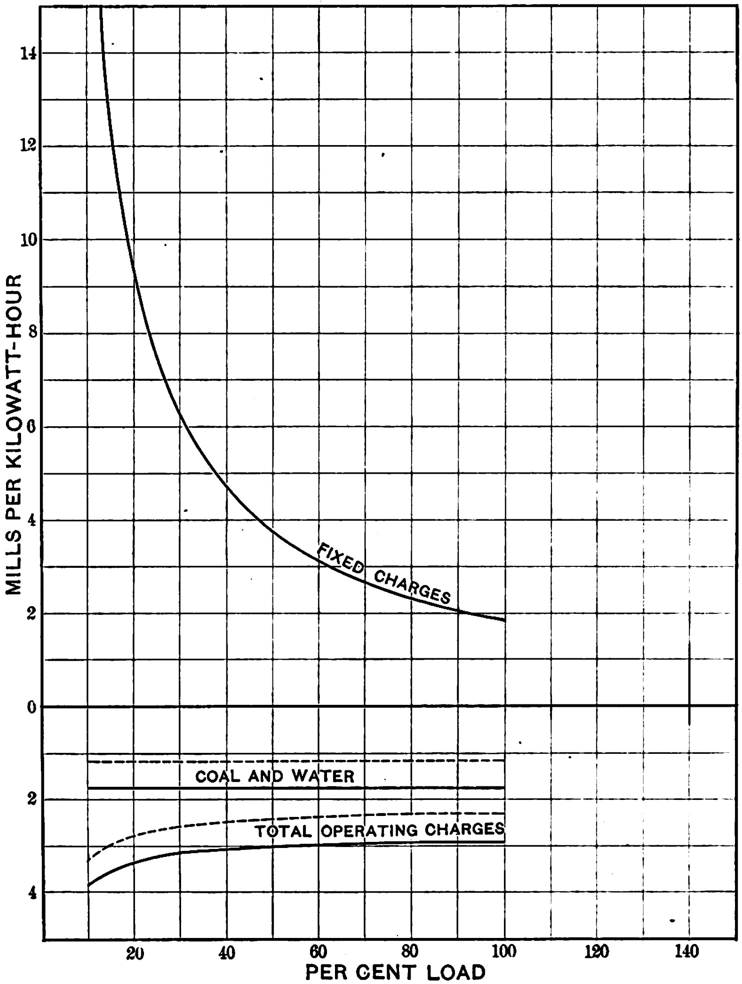

FIG. 4.—Cost of power. Gas-engine plant.
Plant cost = $137.50 per kilowatt.
Interest, taxes, depreciation, etc. = 12%.
Solid lines = coal @ $3.00—14,500 B.t.u. per lb.
Dotted lines = coal @ $1.50—11,000 B.t.u. per lb.

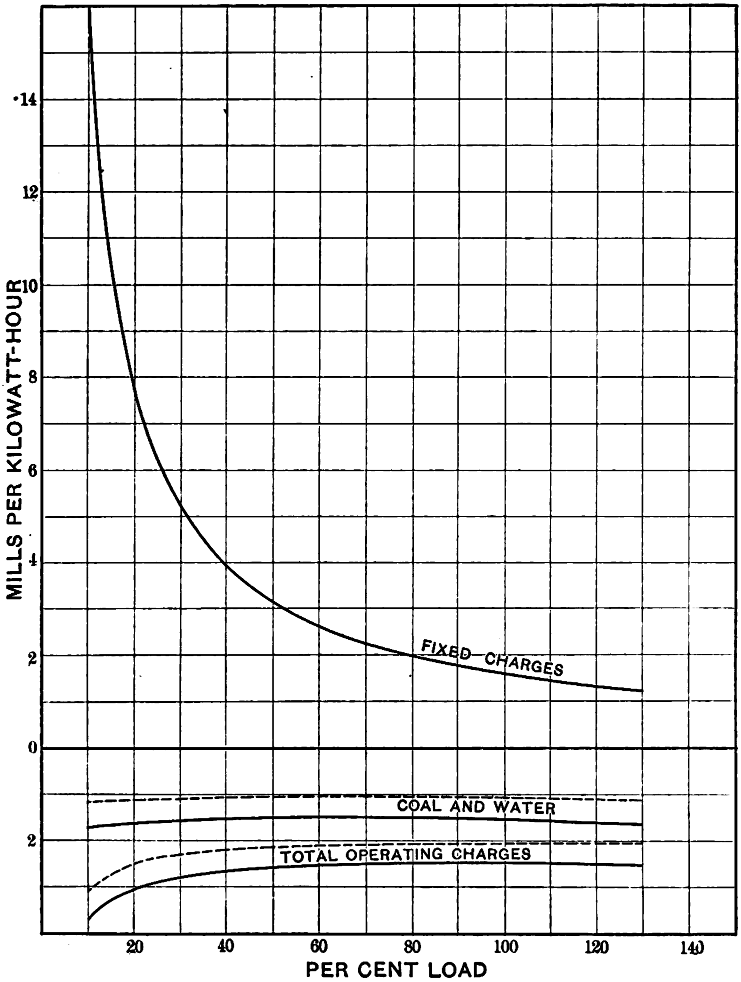

FIG. 5.—Cost of power. Gas-engine and steam-turbine plant.
Plant cost = $120 per kilowatt.
Interest, taxes, depreciation, etc. = 11.5%.
Solid lines = coal @$3.00—14,500 B.t.u. per lb.
Dotted lines = coal @ $1.50—11,000 B.t.u. per lb.

heading of *Coal,* in the reciprocating engine and steam turbine plant, it will be found that this amount has been increased so as to cover the difference between the theoretical amount which had to be assumed in 1906, and the actual amount guaranteed by the manufacturer in 1909.

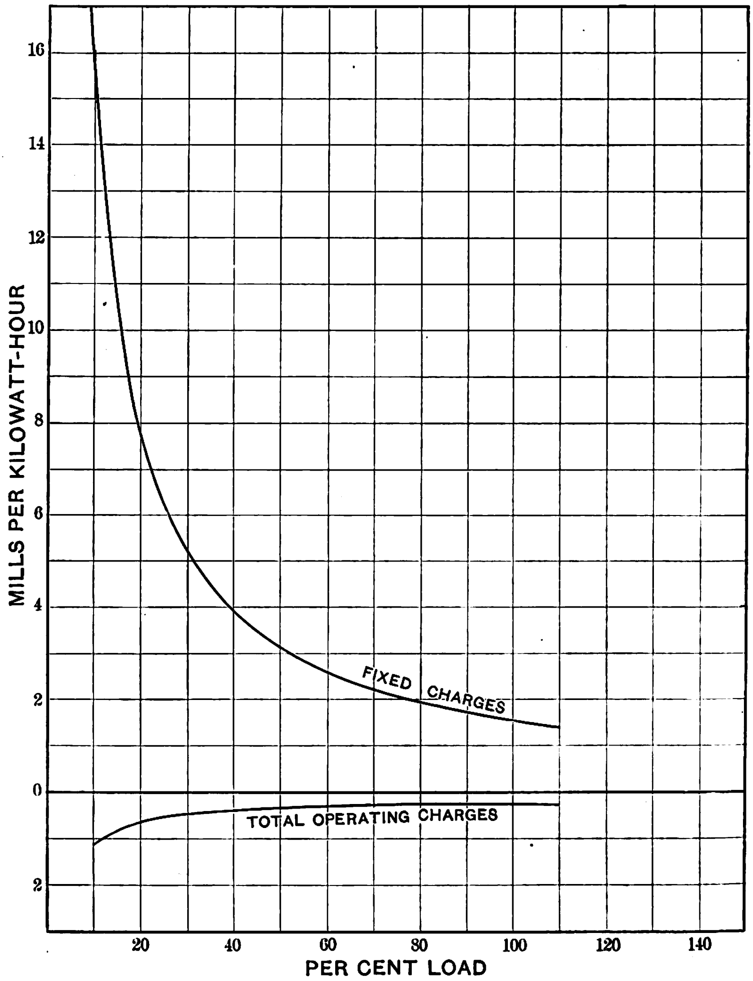

FIG. 6.—Cost of power. Hydraulic plant.
Plant cost = $125 per kilowatt.
Interest, taxes, depreciation, etc. = 11%.

In the following Figs., the cost of delivered coal has been assumed at $3.00 per ton for a high-grade coal having 14,500 B.t.u. per lb. and also at $1.50 per ton for a low-grade coal having 11,000 B.t.u. per lb. so as to illustrate the effect upon the cost of power.

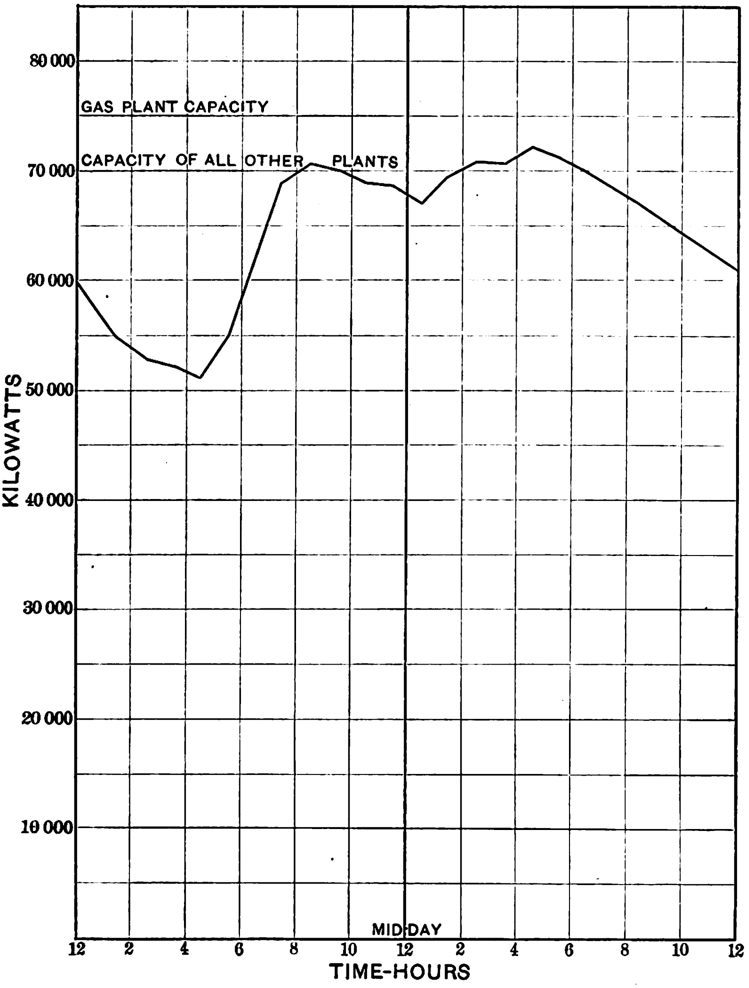

Fig. 7.—Typical industrial load.

Figs. 1 to 6 inclusive show, with various types of plants, the fixed charges upon the upper curve and the operating charges below the axis, so that the sum of the ordinates gives the total cost per kilowatt-hour for any load-factor on the plant. It will be

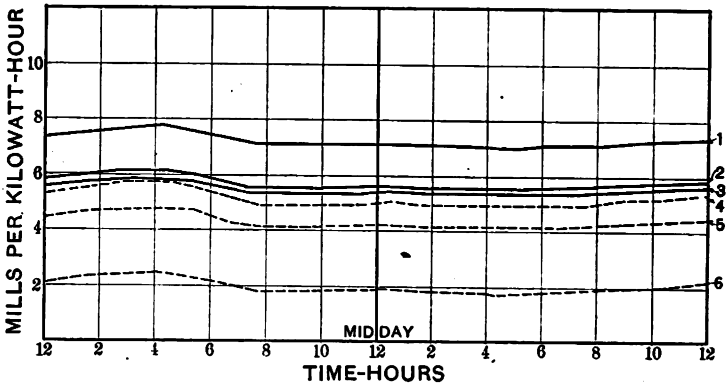

FIG. 8.—Typical industrial load. Cost of power throughout the day.

1. = Reciprocating steam-plant.
2. = Steam-turbine plant.
3. = Reciprocating-engine and low-pressure turbine plant.
4. = Gas-engine plant.
5. = Gas-engine and steam-turbine plant.
6. = Hydraulic plant.

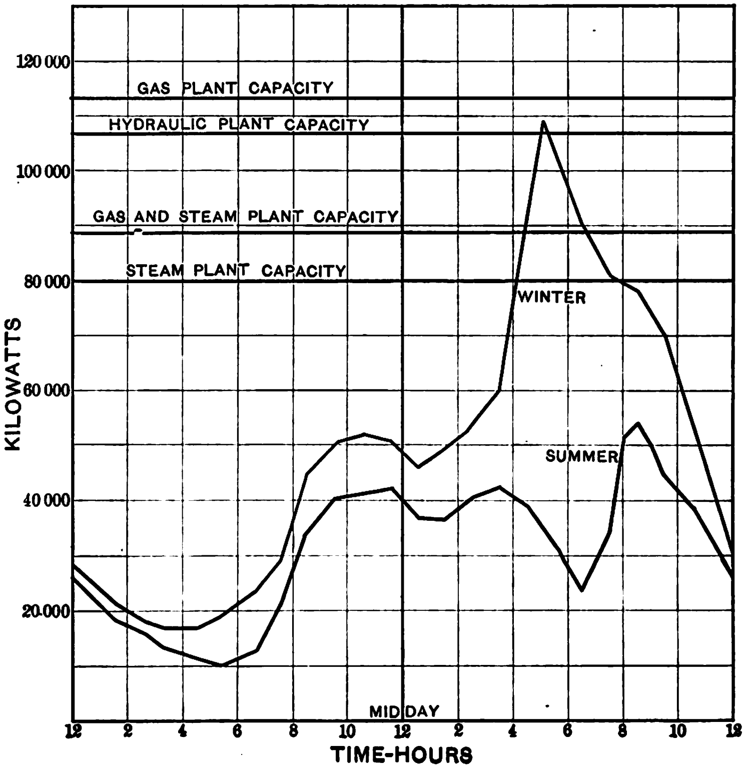

FIG. 9.—Typical lighting load.

noted that all the steam plants are assumed to have 50 per cent overload capacity, sufficient to carry them over a peak-load of two hours, whilst the gas plant has no overload capacity. The combined gas-engine and steam-turbine plant has 25 per cent and the hydraulic plant 10 per cent overload capacity.

Figs. 7 to 14 inclusive show typical industrial, lighting, (summer and winter) and railroad (summer and winter) load-curves. On these Figs. will be found straight lines drawn through points corresponding to the necessary installed capacity of the various types of plants, and a second series of cost curves bringing out in a very suggestive manner the cost of furnishing power at every hour of the day. As an illustration, refer to Fig. 11, which shows the cost of power on a summer lighting load.

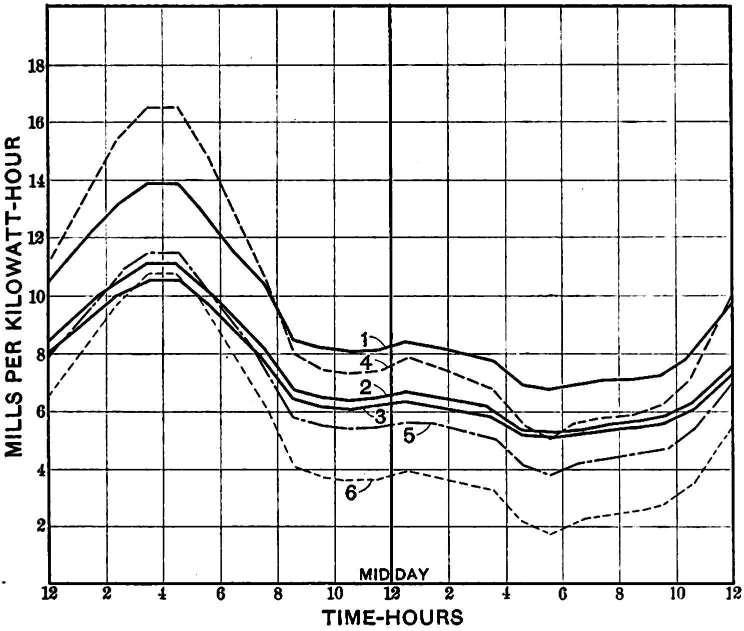

FIG. 10.—Typical winter lighting load. Cost of power throughout the day. Curves, 1 2, 3, 4, 5, and 6 same as in Fig. 8.

During the greater part of the day, No. 4, or the gas-engine plant, is the most expensive, owing to the necessarily high fixed charges. For the same reason, the reciprocating steam-engine plant is also high.

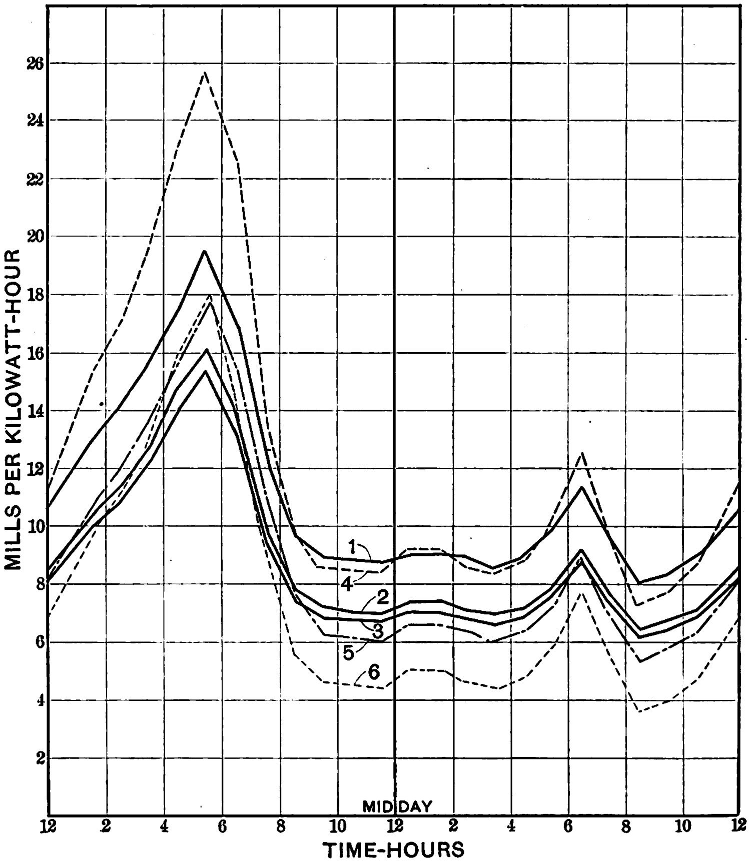

FIG. 11.—Typical summer lighting load. Cost of power throughout the day. Curves 1, 2, 3, 4, 5, and 6 same as Fig. 8.

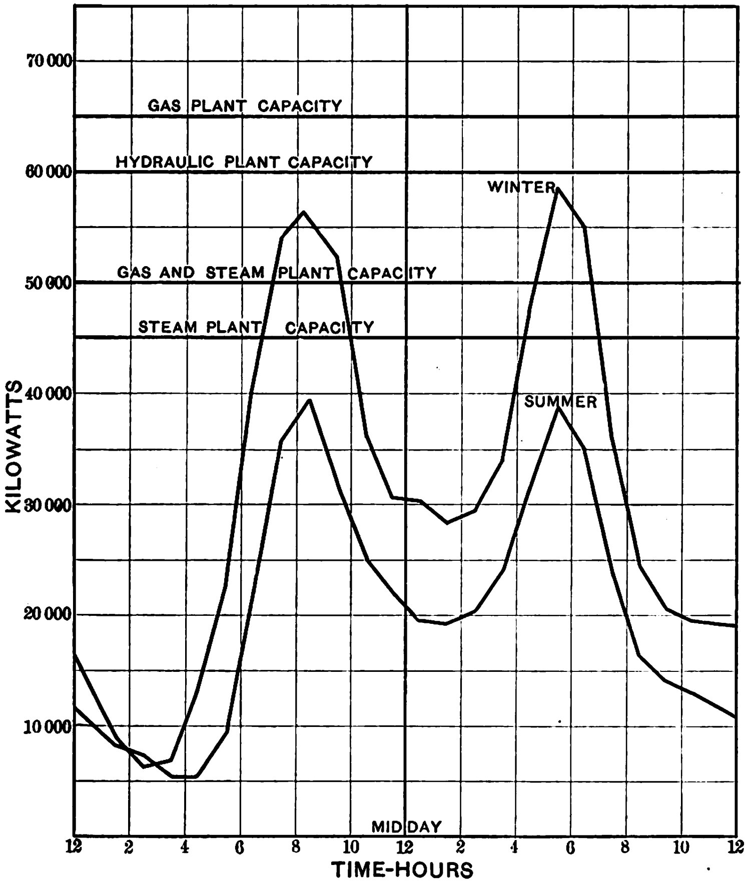

Fig. 12.—Typical railway load.

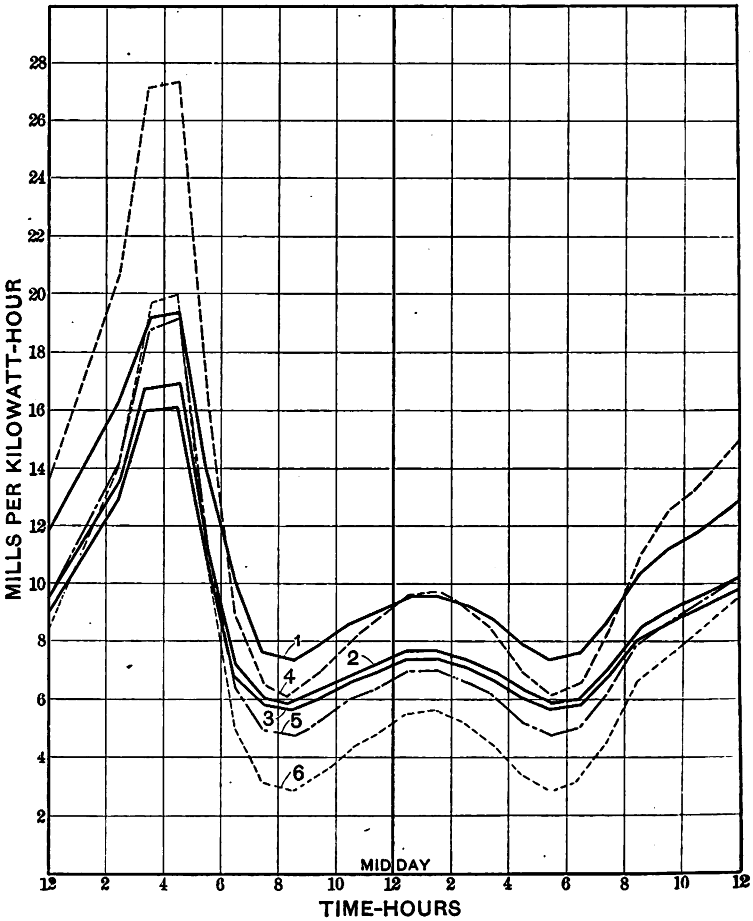

FIG. 13.—Typical summer railway load. Cost of power throughout the day. Curves 1, 2, 3, 4, 5 and 6 same as in Fig. 8.

During the light morning load the hydraulic plant is also handicapped by the fixed charges, but the low operating costs render it the most efficient upon the whole.

Fig. 5, representing the plant in which one-half the installed capacity consists of gas engines and the other half of steam turbines, makes so excellent a showing on all the load-diagrams that we may expect to hear more of this type of plant in the future.

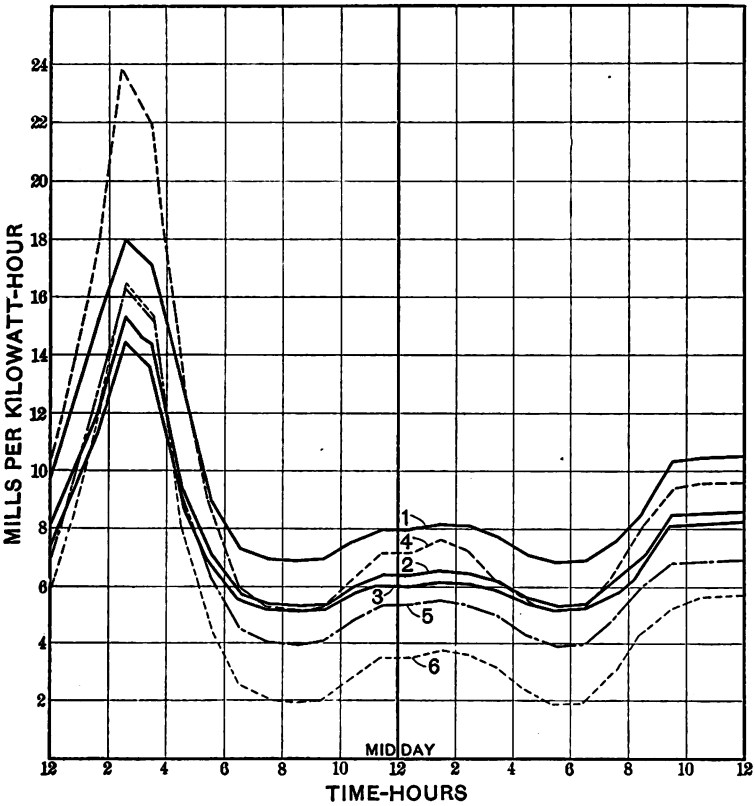

Fig. 14.—Typical winter railway load. Cost of power throughout the day. Curves 1, 2, 3, 4, 5, and 6 same as in Fig. 8.

In all these comparisons it must be remembered that the costs are worked out to the generating plant *bus-bars only*. In practically all cases, therefore, the costs discriminate in favor of

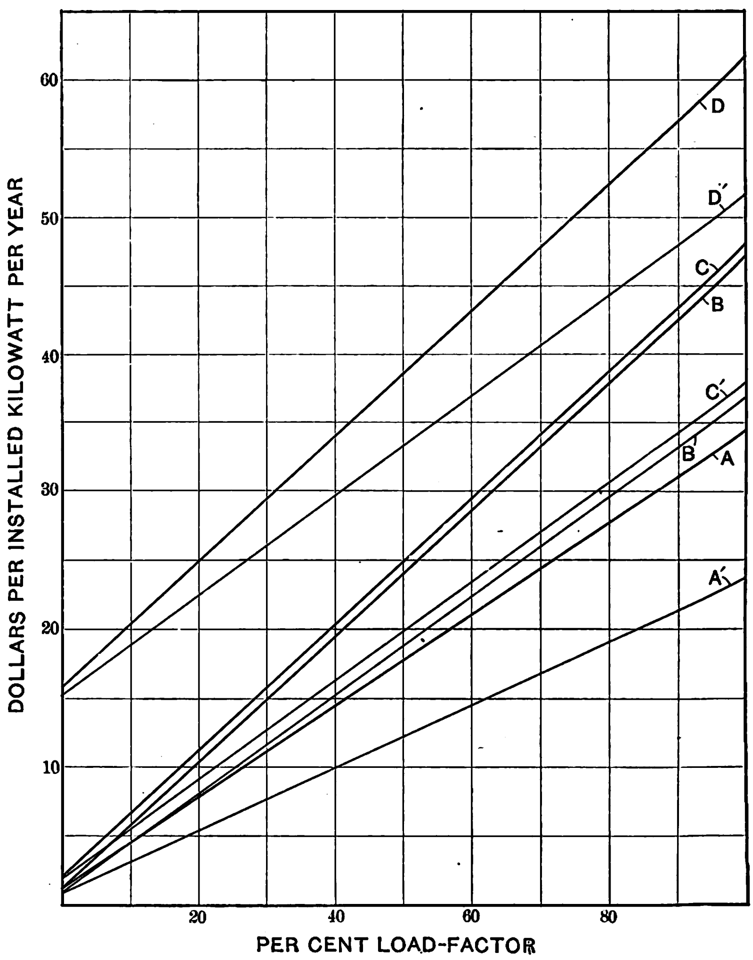

FIG. 15.—Cost of power per kilowatt per year. Reciprocating steam-plant.

Plant cost $125 per kilowatt.
Fixed charges = 11%.
A, B, C, D = coal @ $3.00—14,500 B.t.u. per lb.
A′, B′, C′, D′ = coal @ $1.50—11,000 B.t.u. per lb.
A = Coal and water.
B = A + Mechanical maintenance and operation.
C = B + Electrical maintenance and operation.
D = C + Fixed charges.

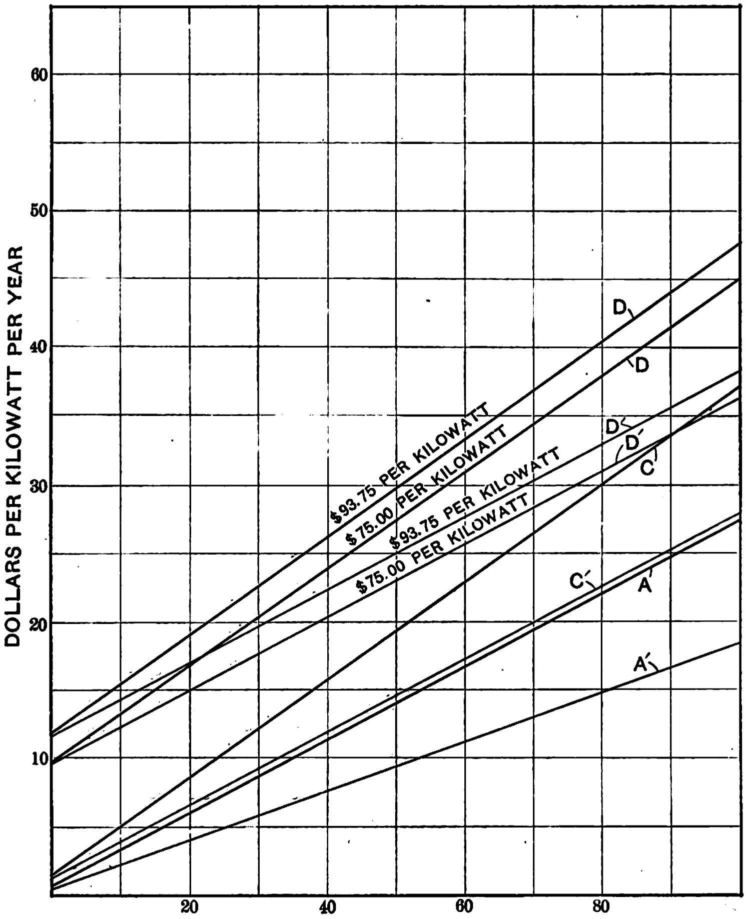

FIG. 16.—Cost of power per kilowatt per year. Steam-turbine plant. Plant cost $93.75 and $75 per kilowatt.
Fixed charges, 11%.
A, B, C, and D same as in Fig. 15 = coal @ $3.00—14,000 B.t.u. per lb.
A′, B′, C′ and D′ " " " " " = coal @ $1.50—11,000 B.t.u. per lb.

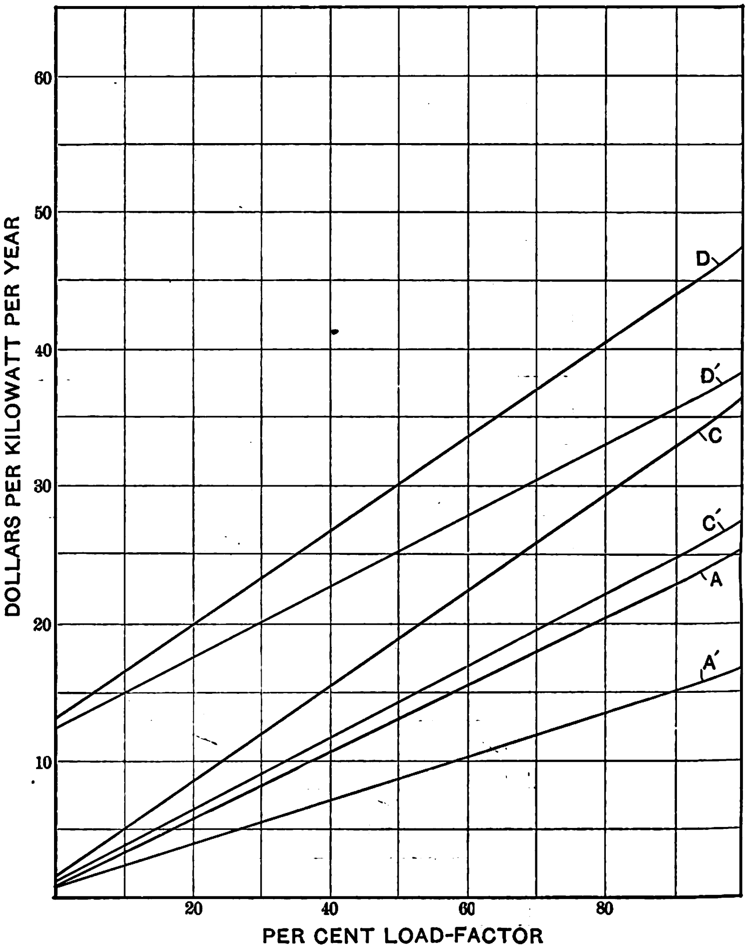

FIG. 17.—Cost of power per kilowatt per year. Reciprocating-engine and low-pressure turbine plant.

Plant cost $100 per kilowatt.

Fixed charges 11%.

A, B, C, D } same as Fig. 15.
A′, B′, C′, D′ }

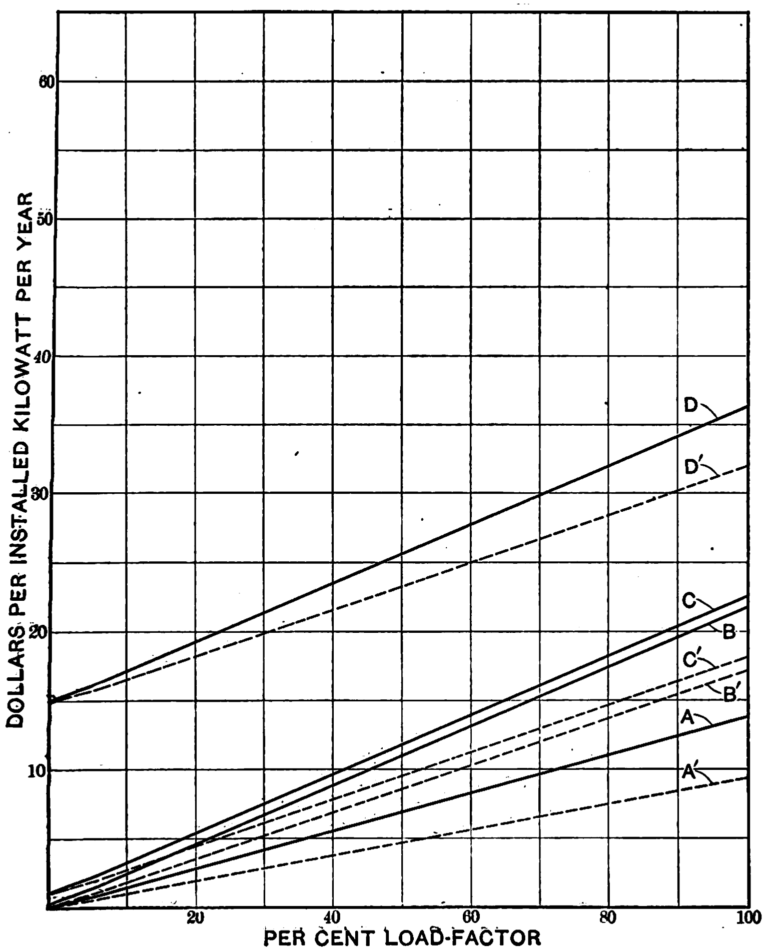

FIG. 18.—Cost of power per kilowatt per year. Gas-engine plant.
Plant cost = $137.50 per kilowatt.
Fixed charges 12%.
Solid lines
Dotted lines
A, B, C, D
} same as Fig. 15.

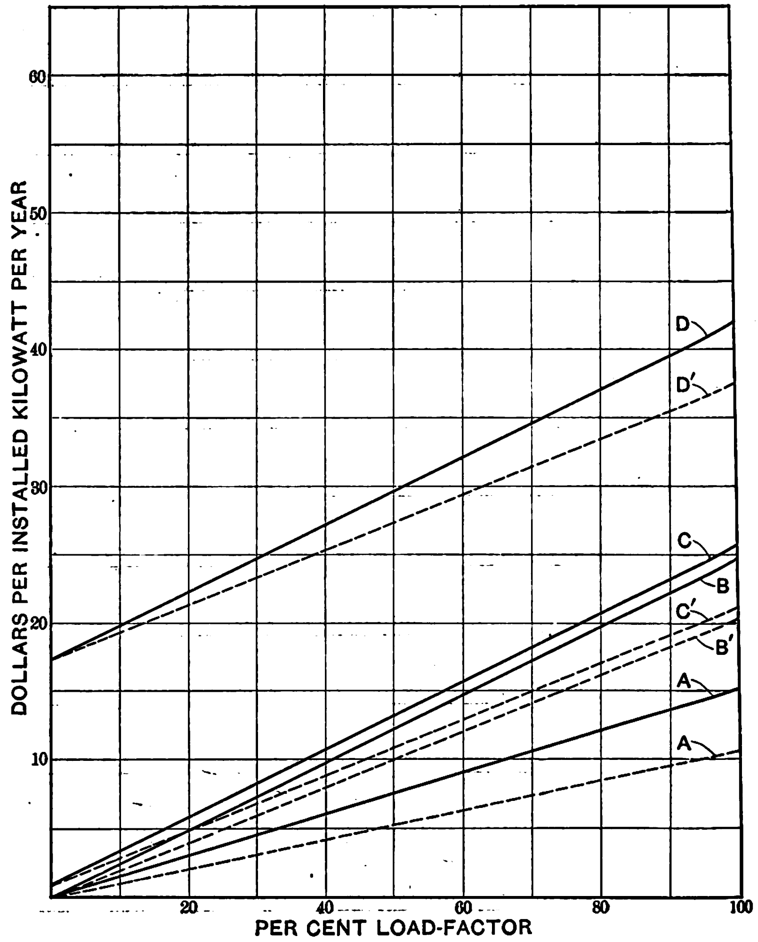

FIG. 19.—Cost of power per kilowatt per year. Gas-engine and steam-turbine plant.

Plant cost = $120 per kilowatt.
Fixed charges 11.5% per annum.
Solid lines
Dotted lines } same as in Fig. 15.
A, B, C, D

the hydraulic plant, which almost invariably has to assume as a part of its expenses, the fixed charges and operating expenses of the transmission lines. Obviously, it was inadvisable to

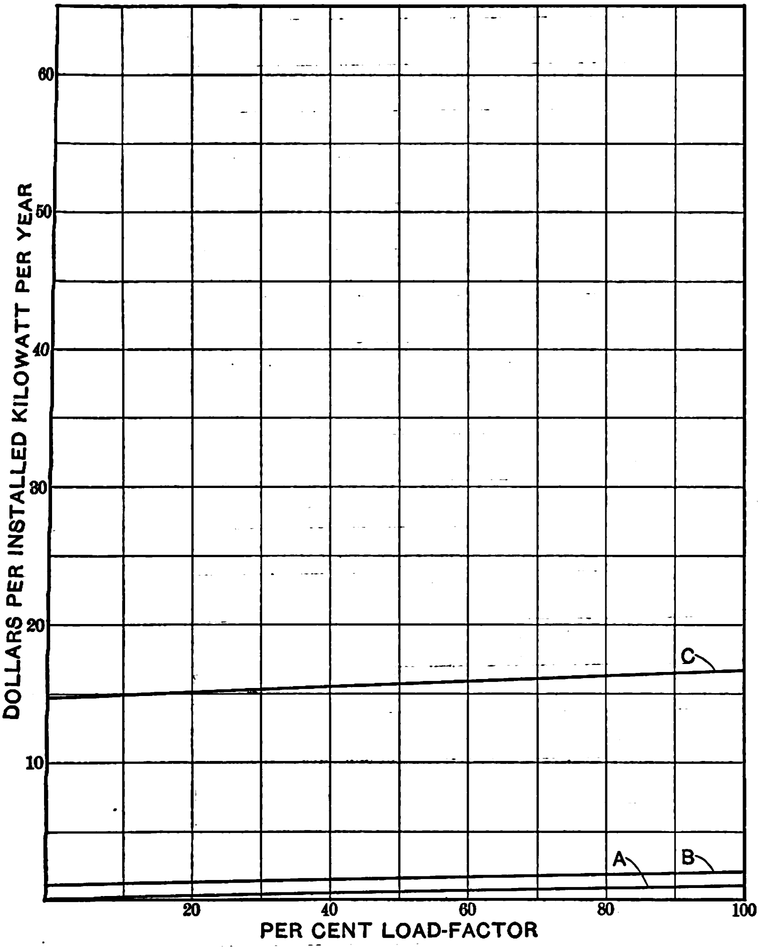

FIG. 20.—Cost of power per kilowatt per year. Hydraulic plant.
Plant cost = $125 per kilowatt.
Fixed charges 11% per anum.
A = Mechanical maintenance and operation.
B = A + Electrical " " "
C = B + Fixed charges.

bring such an unknown quantity into this comparison; but the fixed charges and operating expenses of a long-distance transmission line connecting to an hydraulic plant may be sufficient

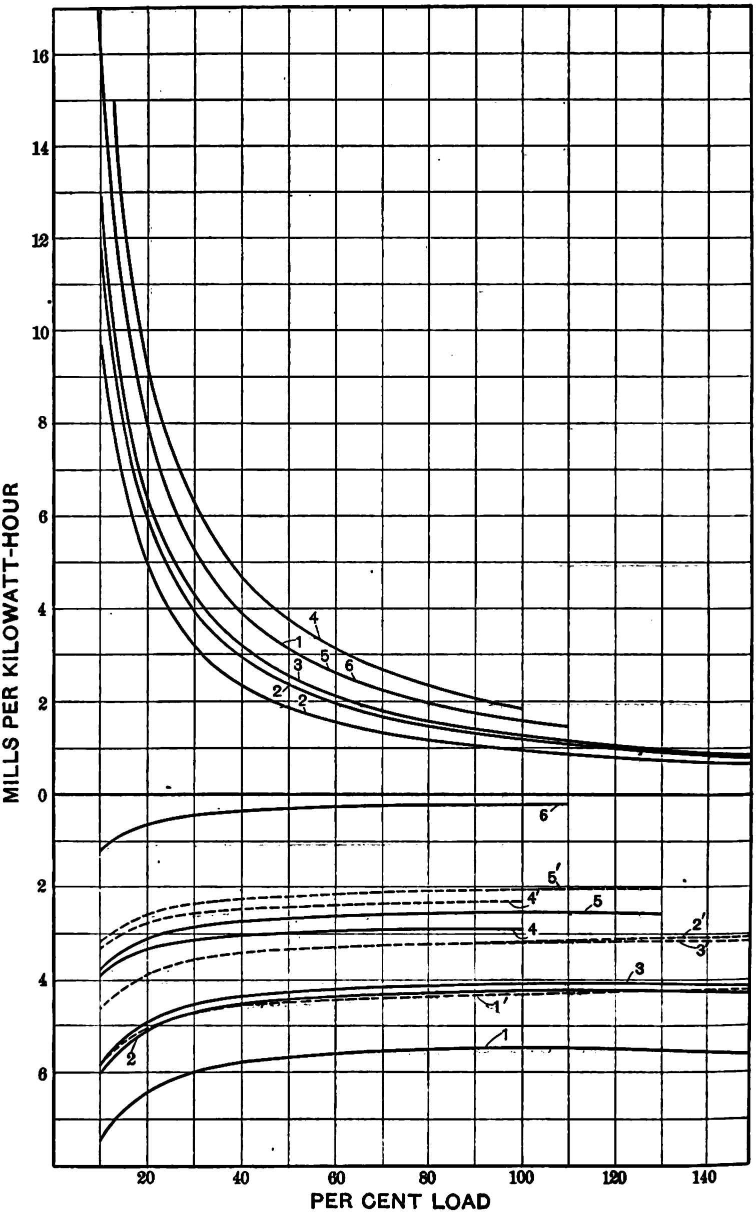

FIG. 21.—Summary of Figs. 1 to 4 inclusive. Curves 1 2, 3, 4, 5, and 6 same as Fig. 8.

in many cases to decide the question of local steam or gas plant versus long-distance transmission from an hydraulic plant.

Figs. 15 to 20 inclusive are calculated from Figs. 1 to 6, and

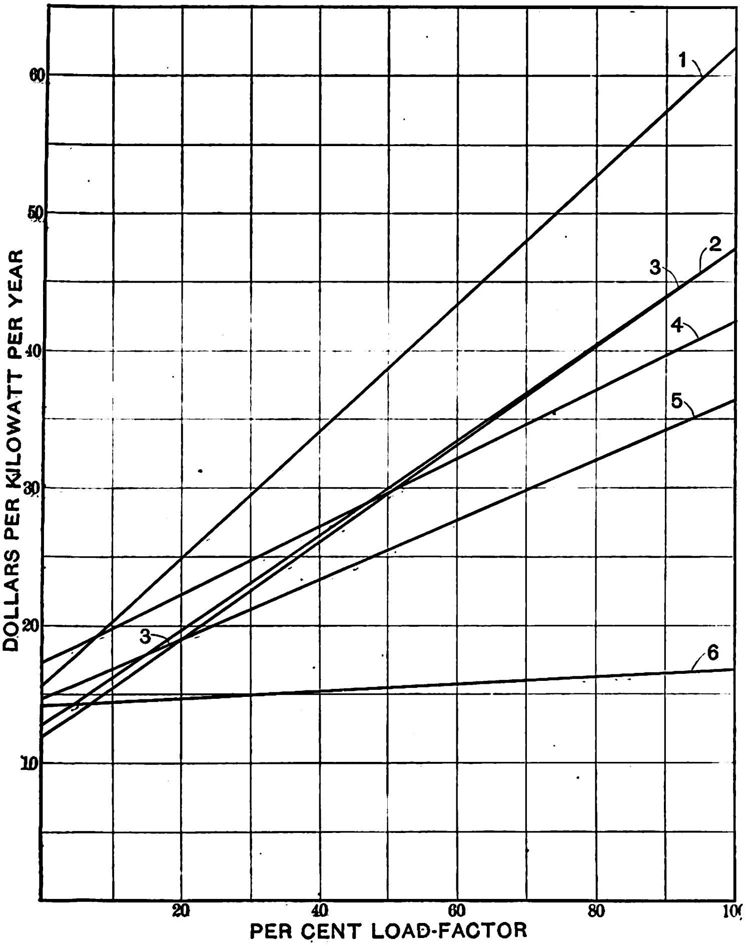

FIG. 22.—Summary of Figs. 15 to 20 inclusive.
Curves 1, 2, 3, 4, 5, and 6 same as Fig. 8.
Coal @ $3.00—14,500 B.t.u. per lb.

show the power-plant costs per kilowatt per annum for various load-factors for each of the six types of plants. Attention is called to the fact that the result shown in Fig. 20 is for power at the bus-bars only, and that this must of necessity be increased by the fixed charges and maintenance costs of the transmission lines and transformers.

In conclusion, the author trusts that the data presented in the

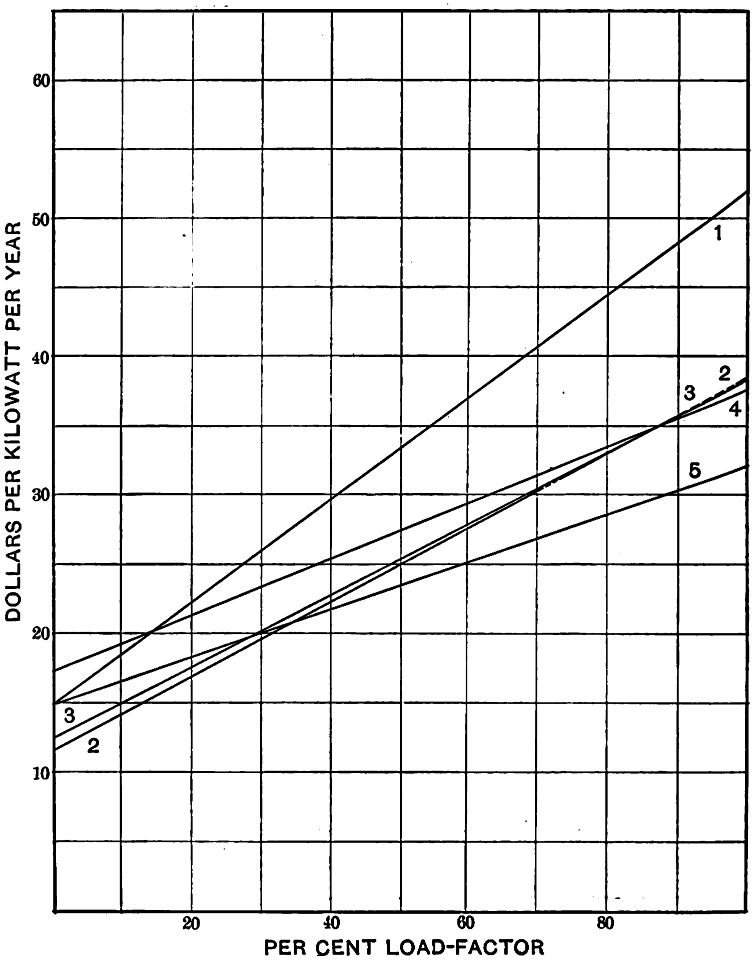

FIG. 23.—Summary of Figs. 15 to 20 inclusive.
Curves 1, 2, 3, 4, 5, and 6 same as Fig. 8.
Coal @ $1.50—11,000 B.t.u. per lb.

shape of 20 curves will be found useful in the preliminary work leading up to the design of a power plant to meet given conditions of load-factor and locality.

*A paper to be presented at a special meeting of the
American Institute of Electrical Engineers
New York, April* 16, 1909.

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(*Subject to final revision for the Transactions.*)

FUNDAMENTAL PRINCIPLES OF INDUSTRIAL EDUCATION*

BY HERMAN SCHNEIDER

It is intended to take the size of the problem, the field that the problem covers, and the end to be attained, and then to build synthetically a solution.

The problem. The problem of education, viewed from the points of industrial progress and the stability of the State, is the training of the mass for efficiency in industrial and civic service. The problem is as big as the United States, because of the interdependence of industrial effort, and because ultimately all education must be framed to strengthen the stability of the nation. In other words, the chief end of education is so to instruct the individual that all individuals as civic units will combine to make the best possible State.

In the United States there are over 18,000,000 children in the public schools; over 17,000,000 of them drop out when the law permits them to, and they go into agricultural, commercial, and industrial life. In the industrial centers they go into the factories; and stores but up to the time of leaving school they have not received one iota of industrial training that is worthy of the name. The size of the problem may perhaps be understood more clearly if it is stated in this way: if these 18,000,000 children were stretched across the country in a straight line, giving one linear foot of space to each child, the line would reach from the upper end of Maine to the lower end of California. That portion which goes through the high schools would reach across the state of California. The rest of the line from Maine to the eastern border of California is drawn into commercial, industrial, and agricultural life at about the age of 15 years, with no industrial training prior to going to work and practically no schooling thereafter. This proportion holds in any industrial town or city.

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*The aim of the Educational Committee is to lay before the Institute members the problems of industrial and technical education. Last year the committee devoted its attention to the problems of technical education. It has been deemed wise this year to present some phases of more elementary industrial training. To this end, Dean Schneider has been invited to give the members of the Institute the results of his study and experience along this line. This he has done in a brief paper which is designed to provoke a discussion of the practical aspects of the training of men as mechanics, draftsmen, etc. A plan for applying the coöperative idea in electrical engineering education was outlined in a paper by Mr. M. W. Alexander, at the annual convention last year. Dean Schneider believes that the coöperative principle applies to industrial as well as to technical training and that it can be carried out in a practical manner.

Scope of the problem. The writer has heard many discussions on industrial education and has read many papers by very able writers. In almost every case the discussion has been contributed by the members of a society that represents a particular branch of industry, or the paper has been written by a man who feels that the trade with which he is most familiar is the most important of all. Members of the American Institute of Electrical Engineers, for instance, in discussing this problem, would usually not consider the educational situation from the point of view of the master tailor, the telephone company superintendent, the head of a department store, the pottery owner, or the building contractor. Investigation on this subject, covering a period of 9 years, discloses the curious fact that a man in almost any business considers the art of his trade as more difficult than the art of any other trade, and he inevitably insists that there must be trade schools to teach the children that go into his particular field of work. He is insisting at present that the public schools shall include specific training for his trade; and there is a general clamor from individuals and societies representing certain industries for the introduction of training in their particular trades into the public school system. Consider for a moment what this means.

If you take the industrial directory at the end of any city telephone book, and attempt to make a list of the trades therein shown, you will find, in a town like Cincinnati, that when you get to the letter E, you have almost one hundred distinct trades. The proposition of putting equipment into the public school system of Cincinnati to train the children for all the different trades in Cincinnati would make so top-heavy an organization, and necessitate so many buildings, that the imagination is staggered. Further, in many lines of industrial work the machinery becomes obsolete about every 7 years; if, then, the trades are to be properly taught in the schools, the equipment for the whole system must be changed at least once in 10 years. The advocates of trade instruction in the public school system evade these very essential facts by saying that the more important trades only should be taught. There are two phases to this latter proposition:

1. Who shall decide which are the more important trades? And how shall public support be obtained from all sources for these few trades?

2. Are the children to be taught a few trades, leaving all the other trades neglected, and leaving the predilections of the children out of question entirely? Or will only a few be trained in the more important trades, and the rest be allowed to shift for themselves as heretofore?

Should this be attempted, it would simply be a partial solution, and a very small one at that, of the whole problem of industrial education. If, for instance, we teach in the public schools the plumbing, machinist, wood-working, and moulding trades, what would be the solution for all the children entering the numerous other trades and commercial occupations?

There is, further, the tax-payer to take into consideration. Let us assume that you and I are residents of the same town, in moderate circumstances, and paying about the same amount of taxes. You have a boy and a girl and I have a boy and a girl. Your boy desires to be a machinist, and the public schools will take care of him; your girl desires to be a stenographer, and the public schools will probably take care of her. My boy wants to be a printer. Have I not the same right to demand that the public schools shall teach my son to be a printer, as you have that they teach your son to be a machinist? Shall the public school system say to my boy: you have got to be a machinist, plumber, moulder, or wood worker, or go without a trade training! My girl wants to be a telephone exchange operator. Will you tell her that she has got to learn her work without any training? Is it fair for the owner of the machine shop to tell the telephone company that it must train its own help, when he demands that the public schools train his help?

In view of the foregoing, it should be obvious that any attempt to put trade schools; that is, schools that teach trades, into the public school system, would result in a tremendous expenditure of money for skilled teachers and for equipment which is not commercially productive. Any attempt to put in a few of the trades would afford only a slight solution of the question. The big problem would still be before us.

The situation. The size of the problem, and its scope, cause us to be confronted by a peculiar situation. In the first place the problem is so comprehensive that there is probably only one organized institution capable of carrying it; namely, the public school system. It ought not to need any argument to prove that private enterprise can not furnish the solution when an average city has 10,000 to 20,000 children to be educated every year, if they are to have industrial education. Figures are available, if they are necessary, to show the futility of private endeavor in industrial education. In the second place, to install a series of trade schools in the public schools is impossible, because of the expense and the inevitable complications.

Let us take account of stock. Every industrial center has a group of school buildings with its quotas of trained teachers. It also has many factories and commercial houses. Under present conditions most of the children who leave the public schools go at once into the industries or stores, and there is no connection whatever between school and shop. The children go to work not because they want to, but because they have to become little bread-winners. Here, then, are many children working in some capacity, and a series of public schools carried on only for those who are fortunate enough to be able to continue in their school work. Since the public school system is the only organized institution capable of dealing with all these children at work, and since the children are also learning a trade and earning money sufficient for their simple wants, it seems that the only complete solution of the problem is a system of coöperation between the schools and the factories for efficiency training and civic training of the young people after they have found their work.

How, then, can this coöperation be built up within the limits of reasonable economy? Fortunately, there are three or four experiments going on which indicate that a coöperative system is feasible in the trades, as it has been shown to be in engineering training. Several of these will be briefly described to indicate the various methods of solution.

The coöperative system. The fundamental principle of the coöperative system is very simple. It is this: the technique or the practical side of the work is taught only in a shop or store which is working under actual commercial conditions, and the science underlying the technique can be taught properly only by skilled teachers. All questions as to who shall supply the school teachers (the shop or the public); the hours the student works, and the hours he is taught; the periods of alternation of shop and school work, if alternating periods be used; and the curricula of the schools—all these are matters of detail to be considered for each particular case.

The economy of the system is at once apparent. In an engineering school, for instance, twice the number of students can be taught at about two-thirds the expense as compared with the four-year theoretical system. The same is probably true in industrial education, for under the coöperative plan the schools will not require any physical equipment; all their money can be used for brains and for buildings for teaching purposes only. There is a further economy to the student. In this case he is earning while he is learning, while under the trade school system he does not earn until he has completed his trade education. Parenthetically it should be stated that no displacement of the present high school courses is contemplated.

At Fitchburg, Mass., the coöperative system is a part of the public school system. The students are divided into two groups which alternate every week. That is to say, this week one-half of the students are in the day school and one-half are in the factories. Next Monday morning these groups will change, and those who are in the school this week will go to the shops, and those who are in the shops this week will go to the school. Since the public school becomes a part of the apprenticeship system, it has a voice in the organization of the apprentice course in the shop, and is *in loco parentis* to the boy, so far as his shop work is concerned. It ought to be obvious that the boy will receive a fair training in the shop because the school is in a measure watching over this phase of his work.

It is not intended, of course, that this plan should apply only to factories. It will apply to a boy learning the tailor trade, the butcher trade, the baker trade, or any other trade. It is necessary, however, to obtain two boys to alternate in the shops.

The course in Fitchburg is of 5 years' duration. At the end of that time the student has been taught the simple science underlying his trade; he has been taught shop mathematics; he has been given a certain amount of cultural work; he has become a fair mechanic. In brief, he is at the beginning of specialization.

It has been found further that the money earned every alternate week, and for full time during the summer, is sufficient to pay for the simple wants of these children. It is also true that there is seldom an instance when a child is hindered by financial conditions from taking such a course.

A number of changes in the system of administration have been found necessary, and these details will be considered to show certain phases of the working of the system. In the first place, the grade school principal is responsible to the school authorities for every boy in his district. When the boy leaves school at the legal age, the grade school principal is required to follow him and ascertain what he is doing. He then consults the parents of the boy and the boy's employer, and the question of the future of the boy is immediately shifted to them. The employer is urged to enter into a combination with the school in the effort to make the boy more efficient at his work, and to give him a little more general education than he would otherwise obtain. The fact is impressed upon the young man and his parents that he ought to make a choice of a trade for life, if possible. If it is found after he has begun work that he has no aptitude for that which he has undertaken, an attempt is made on the part of the school principal, the parents, and the employer of the boy to find the kind of work for which he is best fitted. As some one has expressed it:

> Under the coöperative public school system, the grade school principal pays much less attention to biology and much more to the boy.

The second feature is the work of shop coördination. In order to explain this, the method of operation in the Engineering College at the University of Cincinnati will be used as an example.* The coöperative engineering course at the University of Cincinnati is of 6 years' duration. There are, therefore, six classes, and there is one shop coördinator for each class. The shop coördinator is a college graduate acquainted with shop practice. He spends every morning at the university and every afternoon in the shops. His function is to make a direct weekly coördination of the work of the shop with the technical work of the university. This afternoon, for instance, he may be at the shops of a local manufacturing company, where he will observe the student apprentices at their work. He will know what they are turning out, their " speeds, feeds, and cuts," the angle of the tool, how the batch of work is " ticketed," how the work is set up, the power drive—everything important in connection with the operation. Next week these young men will be grouped together with their classmates for two periods in class, when he will explain the functions of the particular articles on which the students were working in the machine which the local manufacturing company builds.

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* This feature is just being introduced and its effectiveness cannot be stated at the present time.

He will take up all questions of speeds, feeds, cuts, accuracy, etc.; figuratively speaking, he will take from the student apprentices the blinders which would restrict their vision except for this explanatory work. The " ticketing " of the batch of work is gone into, the system of shop routing is explained. Ultimately, all problems of shop organization, shop accounting, cost keeping, shop planning, power transmission, heating, ventilating, lighting, etc., are discussed during the 6 years' course. In conjunction with this, a card system is employed, by means of which everything the student does in the shop that exemplifies a theory taught in the university is called in detail to the attention of the teacher of the theory, so that when the student comes to that particular theory the exemplifications which he has had in his practical work in the shop are called to his attention. It will be seen, then, that out of the student's own experience is drawn much of his course in mechanisms, thermodynamics, machine design, strength of materials, etc.

In the coöperative work in the public schools this close and immediate tie is taken up in a modified way. There will be a shop coördinator for such trades as have a fairly close relationship, rather than by classes, as in the university.

Now in order to show the application of the fundamental principle of the coöperative system mentioned above, but with a deviation in detail to meet a special condition, let us consider the department store. Such a course has been devised and is about to be put in operation. The fundamental principle is strictly held to, but the details are modified to suit the conditions. In any department store, the clerks are not usually busy until 10 o'clock in the morning. A store can get along easily with one-half its clerks from 8 until 10 o'clock. It is intended to divide the force into two sections, one-half of whom will receive instruction this week from 8 until 10 o'clock, while the other section is working; the following week the sections will be changed about. In this particular instance the students do not go to the public schools; the teachers go to the store. It is evident that it is easier to transport 20 teachers than to transport a large number of student-clerks. A number of rooms in the store, such as carpet rooms and lace rooms, are set aside during these 2 hours for the class work, the chairs being removed at 10 o'clock, and sufficient space being reserved for any business which way be necessary up to that time.

It is contended by department store owners that salesmen should know the psychology of salesmanship, and have a fairly expert knowledge of the things they are selling. They should receive, besides, a certain amount of general education. The psychology and the general education are to be taught by trained teachers from the public school system. In order to teach the practical end, the following method has been adopted. Consider, for instance, the shoe department. If one pair of shoes costs $1.85, and another pair costs $1.95, the salesman should know where the difference of 10 cents' value lies. Let us assume that this particular department store buys shoes from a firm in Brockton, Mass. When it makes its next contract for shoes, it will insist that the firm selling the shoes send an expert demonstrator to its store, to explain in detail all the different successive operations in shoe making and all the different elements which make differences in cost. The tanning firm from which the shoe manufacturer buys its leather will be required to send to the store an expert to exemplify practically to the students the different grades of leather in a hide, methods of preparation, and why one kind of leather is used in one part of a shoe, and another in another part of a shoe. It has been found that the shoe manufacturers will very gladly enter into any scheme of this sort. He would in fact be a very short-sighted manufacturer who would not. This same general idea is followed in all of the other departments, such as jewelry, linen, silk, furniture, etc.

Other instances might be cited of experiments now in operation based on the simple principle of the coöperative system, with changes in detail, but the scope of this paper will not permit their consideration here.

It is intended to call particular attention to the fact that under this plan the public school deals with the whole general problem, deals with it without physical equipment. It is, in other words, a return to the old apprenticeship system with something added; namely, definite instruction in efficiency by trained teachers, and additional instruction aiming toward better citizenship.

The writer realizes that many manufacturers will say that a scheme which brings two sets of students into any work on alternate weeks—assuming that the alternate-week system be used—is not practicable, and will result in demoralization. The only answer to this is that three years of operation at Cincinnati, and shorter periods of operation elsewhere, have demonstrated that the criticism is untenable. Two alternating students work very well together and there is no confusion. Emphasis is laid upon this, because before the coöperative system was started this objection was the greatest obstacle in the way of its adoption. Men who were skeptical about this phase of the work have become enthusiastic over the smooth working of the system after a fair trial.

It is with hesitancy that a certain feature of industrial education is touched upon at this point, in view of the many propoganda that are being made in favor of it. There is a belief that there will be a tendency to swing too far in the " practical " direction, and that the impetus now being given to trade education may result in a too material training of the youth of the country, injuring to a certain extent that phase of education which should tend to the training of all civic units for civic service. In other words, the fact that every unit is a citizen of a republic, and that the republic depends for its stability upon the character of the mass, must not be overlooked. Fundamentally and primarily, as stated at the beginning of this article, the training of men to become citizens of a republic must be a vital part of any worthy system.

The object of all education is to make good citizens, and the first duty of a good citizen is to earn his own living. The second duty is to be a good citizen in the civic sense. All education, whether industrial or otherwise, should be directed toward these two very important phases of our national life. Here again is a very strong reason why the whole problem of industrial education should be solved in the public schools, where there will be the check of conservatism as to the character of the work, and where the whole solution will be under the direction of men who are servants of the public, and who naturally and by tradition look upon the problem with the widest and safest vision.

The writer has purposely omitted going into definite details, curricula, etc.; for instance, as to how a student should be instructed in arithmetic, algebra, and chemistry. At the present these do not constitute the problem, and even if they did, enough work has been done in different kinds of schools to demonstrate clearly the character of instruction which ought to be given. The problem confronting us is the method of comprehensive action for the whole situation in the United States. We can not adopt the German system, for the simple reason that the social stratification in Germany is horizontal, while in this country it is vertical. That is to say, the problem in this country is to find the highest elevation which any man's ability will permit him to reach, and to get him to that elevation. It must be evident that with this system in general operation in the public schools, admission to the university would be by natural selection. In the future, when the system becomes general, only those men will receive the higher education, who will make the best use of it, and hence will give the greatest return to the State.

The writer believes that the American Institute of Electrical Engineers, a national body of men whose personal interests are dovetailed so closely with the whole industrial welfare of the country, can do nothing better than to stand for a movement involving a broad, systematic, and thorough industrial and civic training under a national system.

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(*Subject to final revision for the Transactions.*)

ELECTRICITY AND THE CONSERVATION OF ENERGY

BY LEWIS B. STILLWELL

In any problem, accurate and, so far as practicable, concise statement is essential to proper consideration and correct solution. The economic problems which present themselves when the complex and far-reaching subject, Conservation of Natural Resources, is considered, can be approached best by first stating and defining them with reference solely to physical and economic facts and relations without reference to political boundaries or limitations. To approach the subject by considering, first, real or supposed difficulties imposed by the respective rights and duties of states and of the nation is to discuss method of treatment before diagnosis. We should consider the problem first as if there were no such thing as states within the union, assuming, for the time being, within the federal boundaries the existence of one central and absolute authority. The question what, upon this assumption is economically desirable, is that which the engineering profession should first agree upon and, if possible, state in a manner which will be understood by the general public.

Conservation as applied to our natural energy resources means utilization without unnecessary waste. In a broader sense it means also development along lines which will not only utilize but increase those resources; for example, as regards water powers it has relation to the maintenance and renewal of forests affecting variation in stream-flow, and the construction of storage reservoirs which, properly used, are capable of adding greatly to that part of the run-off which can be used for industrial purposes and navigation.

Much has been uttered recently with reference to these relations which can not be expected to hold good in the light of that clearer knowledge which will result from further study and experience—much that is erroneous and misleading even when examined critically in the light of facts now ascertained and determined. General statements from sources commanding the attention and arousing the interest of the public are necessary first steps in turning a nation from reckless waste and almost unrestricted appropriation of natural resources by individuals, to a policy of wise conservation, having due regard to the common interest now and in the future. Those first steps have been taken, on the whole, in an admirable manner. Public attention has been arrested. Public interest has been aroused. Public and legislative opinion are forming. Obviously, it is of the utmost importance that our engineering societies should take an immediate and active part in working out the complex problems of conservation and, if possible, in directing the formation of public opinion along lines that will result in the enactment of just and wise laws.

The economic utilization of our natural resources is the fundamental problem of all engineering. If the president of the United States were to summon a conference of governors at the White House for the purpose of considering and promoting reforms in current medical practice, the medical profession undoubtedly would be greatly interested, and would manifest its interest by assuming proper and unchallenged prominence in discussing the questions raised. If such a conference were to assemble for the avowed purpose of initiating reforms in the machinery and methods for the administration of justice, it is not to be doubted but that the lawyers would manifest their vital interest not only by exposition and discussion, but also by actual leadership.

The conference of governors in May, 1908, called by President Roosevelt to consider and advise regarding conservation of the natural resources of the United States, raised questions in respect of which the engineer occupies a position closely analogous to that which the medical doctor holds in respect of medical practice and the lawyer in respect of legal procedure and administration.

The analogy is not perfect, nor does responsibility for final decision rest exclusively upon the engineer, but it is peculiarly the patriotic duty of the engineering profession to enlighten the public by unbiased consideration and accurate exposition of essential pertinent facts, physical and economic.

I propose in this paper: 1. To illustrate the function of electricity in the conservation of natural resources. 2. To summarize statistically the present power requirements of the United States and present certain data (necessarily far from complete) relative to water power available. 3. To point out certain economic bearings of the plan which proposes the imposition of a tax on water powers, and the use of the proceeds for improvement and construction of inland waterways.

THE FUNCTION OF ELECTRICITY IN CONSERVATION

The part which electricity is destined to play in the conservation of our energy resources is demonstrated clearly by what it already has accomplished. Three typical illustrations will suffice: 1. The saving of coal by the utilization of water power, as illustrated by the plants of the Niagara Falls Power Company. 2. The saving of coal by the substitution of large and highly efficient steam plants for smaller and less efficient plants, as in the case of the Newcastle-upon-Tyne Electric Supply Company. 3. The saving of coal used for transportation purposes by the substitution of large and highly efficient engine units for comparatively small and inefficient locomotive units, as accomplished, for example, by the Interborough Rapid Transit Company of New York.

In each case the economy is due primarily to the fact that we can now use for transmitting and distributing power, the electricity produced in dynamos, distributed by conductors, and utilized by motors—all of remarkably high efficiency.

The Niagara Falls Power Company. During the year 1908, the plants of the Niagara Falls Power Company delivered an output of 560,000,000 kw-hr. Had this output been generated by large modern central stations using steam power, their consumption of coal would have approximated 2000 tons per day. Were the users of Niagara power dependent to-day upon their own individual steam plants, they would use in the aggregate not less than 3000 tons of coal per day; in other words, more than 1,000,000 tons per annum. If this power were replacing steam, as used under average conditions in our manufacturing cities, instead of being used for the most part in supplying power to a comparatively small number of customers using large blocks of power, it would replace and save nearly 2,000,000 tons of coal per annum.

Important as is the saving of coal from the standpoint of conservation of our natural resources, perhaps the most striking feature of the Niagara power enterprise is the demonstration which it affords of the great industrial value of cheap power; the greater part of the output of the plants being utilized to-day by electrochemical industries of great value to the community, all of which have been stimulated and some of which owe their very existence to their ability to secure power at very low cost.

The North-East Coast Power System. The North-East Coast Power System, supplying electric power to the great industrial district in and about Newcastle-upon-Tyne, effects a very important economy in coal consumption. In a paper presented at the Middlesbrough meeting of the British Iron and Steel Institute in 1908, Mr. Charles H. Merz, the engineer under whose able direction this large enterprise has been carried out, shows that the economies resulting from centralization of power development and electric distribution have led to the construction of plants now in operation, aggregating 102,000 h.p. installed; that additional plant aggregating 34,600 h.p. is under construction; that during the last 4 years the demand has increased at a rate averaging 20,000 h.p. per annum; that to-day every shipyard on the north bank of the Tyne is purchasing practically all of its power supply in the form of electricity; that the system is now:

> Responsible for the supply of current to eighty (80) miles of electrified railway, four tramway systems, the lighting in towns having populations aggregating over 700,000, motive power to the extent of 85,000 horse-power and electrochemical works of over 12,000 horse-power.

Not only has Mr. Merz established highly successful steam-driven power plants in a district where the cost of coal ranges from 7s. to 9s. per ton, but he has demonstrated that important economy of coal consumption results from the supply of electric power to the collieries for their mining operations.

Referring to this very interesting feature of the development, Mr. Merz says;

> The output of coal from Northumberland and Durham in 1906 was over 52,000,000 tons and, according to the Report of the Royal Commission on Coal Supplies, between six and eight per cent of the total coal brought to bank is used by the collieries for the purpose of power generation. From the make of coke * * * it appears that about one-fifth of the coal mined on the northeast coast is converted into coke. Making a liberal allowance, therefore, for the power at present used from the surplus heat resulting from the coking process, the collieries of Northum-

berland and Durham must burn for their power requirements some 2,500,000 tons of coal per annum. As the almost invariable rule is to work non-condensing, as the steam piping is usually long, and as a large portion of the load is intermittent, it is certain, and is proved by experience in this district, that the same power can be provided electrically in a large central power station by the consumption of less than a quarter of this coal. Apart, therefore, from the efficient utilization of waste heat, apart from the saving of coal in ship-building and engineering works, and apart from the saving resulting from the electrification of railways, the application of electricity to coal-mines in this district, when as complete as that to the Tyne shipyards, will render available for outside sale over 1¾ millions of tons coal, equivalent to, say, over half a million sterling per annum.

The Power Plants of the Interborough Rapid Transit Company of New York. The output of the power houses of the Interborough Rapid Transit Company, New York, for the year 1908, was 409,000,000 kw-hr. The consumption of coal was 494,000 tons. In a paper presented at the 214th meeting of the American Institute of Electrical Engineers, by the writer and Mr. H. St. Clair Putnam,* comparison was made from the company's operating records of the fuel consumption upon the Manhattan elevated lines during the year ending June 30, 1901, when steam locomotives were employed, and during the year ending June 30, 1904, when electricity was used. I quote from this paper:

> Referring to the period first mentioned, one pound of coal produced 2.23 ton-miles, if the weight of the locomotive be included, and 1.5 ton-miles, if the weight of the cars only be considered.
>
> During the latter period (electric traction), one pound of coal burned at the power house produced 3.85 ton-miles; excluding weight of locomotives, therefore, the ratio of ton-mileage per pound of coal in favor of electric operation was 2.57 to 1. Including weight of locomotive it was 1.72 to 1.
>
> The average speed under electric operation was approximately 2 miles an hour greater than that attained by steam, and if correction be made for this difference, the ratio of ton-mileage per pound of coal, excluding weight of locomotives, is approximately 3 to 1, and, including locomotives, 2 to 1 in favor of electric traction.

If, therefore, we can conceive the possibility of operating today, by locomotives, the entire service of the elevated and subway lines of the Interborough Company, it appears that the saving in coal consumption effected amounts, to not less than 988,000 tons of coal per annum.

In each of the three typical cases cited. it will be noted that electricity results in a radical economy of coal. That it also results in a material saving of household and other property which, in industrial communities using large numbers of small steam plants, suffer rapid deterioration by the effects of smoke and dust; that it tends strongly to improve the appearance of our cities and conditions which affect comfort and health are facts not all of which are strictly pertinent to a consideration of the subject before us, but may nevertheless be mentioned in this connection.

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* TRANSACTIONS A. I. E. E., 1907. Vol. xxvi, p. 31.

Where steam is used to generate power in large plants from which electricity conveys it to users, economy results not only from the employment of comparatively large power generating units, but also from the introduction of plant economies and a degree of skill not attainable in smaller plants.

INDUSTRIAL USE OF POWER.

From the latest available census returns, the following tabulation of aggregate capacity of prime movers used in the United States at the dates and in the respective industries mentioned, is compiled:

	Installed horse power
Manufactures, census 1905	12,765,594
Mines and quarries, census 1902	2,753,555
Street railways, census 1902	1,359,289
Electric light and power stations, census 1902	1,845,048
Custom flour, grist- and saw-mills, census 1900, (omitted from census 1905)	883,685
Telephones, telegraph and fire-alarm systems, census 1902	3,148

The United States census reports since 1870 afford data from which interesting conclusions in regard to the respective rates of increase of power used for various industrial purposes, the relative proportions of steam and water power now in service and the enormous growth of electric motor applications may be investigated. Such a study has been made by Mr. H. St. Clair Putnam, of New York, and the results set forth in an interesting paper on "Conservation of Power Resources,"* presented by him at the conference on the Conservation of Natural Resources, held at the White House, May 13–15, 1908. Mr. Putnam employed the method of constructing curves based upon census statistics beginning with the year 1870, and projecting the resulting respective curves from the dates of the latest census figures to the year 1910. Making due allowance for the check to our industrial progress, which began in 1907, it is safe to say that at the present time the aggregate horse power of prime movers installed for industrial use in the United States, exclusive of steam railways, approximates 25,000,000.

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* PROCEEDINGS A. I. E. E. Vol. xxvii, p. 1397.

In round numbers, 50,000 steam locomotives are owned by our railway systems. Based upon maximum drawbar pull, these locomotives would be capable of developing about 30,000,000 h.p., but the average power actually developed on a 24-hr. basis, when averaged over the entire year, approximates only about 2,000,000 h.p.

Were all the railways of the United States operated by electricity generated in large and properly located power plants, the aggregate installed capacity of these plants would approximate 4,000,000 h.p.

Of the grand total of 25,000,000 h.p. installed for industrial purposes, exclusive of steam railway operation, water motors represent, in round numbers, 5,000,000 h.p., and gas engines and oil engines about 800,000 h.p.

I quote from Mr. Putnam's paper:

> Prior to 1870, the use of water power in manufactures exceeded that of steam power. Water power expressed in percentage of the total power employed has since steadily declined, falling from 48.3% in 1870 to 11.2% in 1905. During the corresponding period, steam power increased from 51.8% in 1870, to 78.2% in 1900. The census of 1900 showed a marked falling off in the rate of increase in the percentage of steam power used as compared with the rate prior to 1890, and this was accentuated in the census of 1905, when the percentage of steam power fell to 73.6% of the total. This check to the ascendency of directly applied steam power was due to the introduction of electric power. In 1890 electric power was negligible. In 1900 it constituted 4.8% of the total. In 1905 this had increased to 11.8%—a marvelously rapid growth when the aggregate increase of over 1,000,000 h.p. in five years is considered. If the present rate of increase prevails until 1910, electric power will have reached 18 per cent of the total and steam power will have dropped to 68%.

The facts to which I have called attention point unquestionably to further and rapid progress of the work of substituting electric motors for small steam engines. While this development has made a highly significant beginning in the field of transportation, in the replacement of steam locomotives for elevated and subway service and for terminal operation, it has already covered a substantial portion of the entire field of stationary operation. Its economies and their advantages are fast becoming matters of common knowledge. The cost of electric apparatus in general has decreased materially in the last decade, and the day appears not far distant when the isolated steam-engine plant as used for general industrial purposes will be practically banished from our cities.

Our ability to utilize in the near future a large proportion of our water powers depends primarily upon the distance across which power can be electrically transmitted at practicable costs. This in turn depends upon the limits of potential against which transmission lines can be insulated in a manner which secures reasonable continuity of service. No precise limit of practicable distance can be fixed, nor is it necessary here to enter into a detailed discussion of the subject. It is sufficient to point out that power to-day is being transmitted from Niagara Falls to Syracuse, a distance of 160 miles. In California, it has been transmitted successfully a distance exceeding 200 miles. While 200-mile transmission does not bring every water power of the country within reach of an adequate market, it does obviously suffice as regards a large proportion of our hydraulic resources not as yet utilized.

AVAILABLE WATER POWER

From a purely physical standpoint, an estimate of horse power available in the case of a given stream requires accurate topographical survey and careful measurement of flow extending over a considerable period of years. Much work of very great value has been accomplished in these directions by the United States Geological Survey but much still remains to be done. Systematic prosecution of this work is essential to the ultimate solution of our problems of power conservation, and the influence of the engineering profession should be strongly exerted to insure the effective extension and continuance of these surveys and measurements.

The majority of estimates of " water power available in the United States," which have been made, do not and cannot pretend to be exact. Obviously, there is a vast difference between the aggregate horse power which may be considered available, if the problem be looked at from a purely physical standpoint without reference to cost of development, and the amount which is available if cost of development and transmission to an adequate market is considered.

From the economic standpoint, determination of the aggregate, the horse power which a stream is capable of developing, involves a step-by-step examination of its profile from its source to its mouth, the approximate location of sites where the gradient and other topographical features indicate the practicability of development within the limit of practicable cost as fixed by cost of competing steam power, and the summation of the powers thus located. Following this general method, Mr. M. O. Leighton, chief hydrographer, United States Geological Survey, estimates the available water power of the upper Mississippi river and tributaries at 2,000,000 h.p. and that of the southern Appalachian region at approximately 3,000,000 h.p. The aggregate available water power in the state of Washington has been estimated at 3,000,000 h.p. and that of northern California at 5,000,000 h.p.; but these figures are merely approximations and cannot be regarded as authoritative.

The report of the Inland Waterways Commission acting as the Section of Waters of the "National Conservation Commission," before the recent Joint Conservation Conference in Washington, states:

> The theoretical power of the streams is over 230,000,000 horse-power; the amount now in use is 5,250,000 horse-power. The amount available at a cost comparable with that of steam installation is estimated at 37,000,000 horse-power, and the amount available at reasonable cost at 75,000,000 to 150,000,000 horse power.

The assumptions and facts upon which these estimates are based are not set forth in the report referred to with that precision which is essential to correct judgment of their value. The amount named as "available at a cost comparable with that of steam installation," namely 37,000,000 h.p., exceeds the aggregate mechanical power now in use within the borders of the United States, and suggests the enormous saving in coal which would result from anything like a general development and utilization of our water powers.

But whatever may be the aggregate amount which ultimately can be utilized, certain guiding facts are obvious and cannot be controverted. Among these are: 1. Under average conditions every hydraulic horse power utilized for industrial purposes in 10-hr. service saves at least 7.5 net tons of coal per annum. 2. Present knowledge does not permit us to obtain from coal burned for power purposes, even under conditions of best commercial practice, more than 10 per cent of the energy which it contains: under average conditions less than 5 per cent is utilized.

3. Electricity enables us to substitute a few and comparatively efficient steam plants for large numbers of small and relatively wasteful installations; thus effecting important economies not only in fuel consumption but also in other directions. It also enables us to transmit and utilize in available markets a very large proportion of the aggregate water power of our streams.

In view of these facts, it will be admitted that from the standpoint of conservation of our power resources, the attitude of the federal and state governments should be such as will hasten and not retard the development of our water powers. Any policy which operates to retard this utilization is a danger to the community, not only because it tends to increase the average cost of power and, therefore, of transportation and the manifold products of our manufacturing industries, but also because it tends to prolong and even increase the, at present, necessarily wasteful utilization of coal supplies which can never be replaced. Such a policy, therefore, is on its face in direct contravention of the true principles of conservation.

Water powers not hitherto appropriated under existing laws belong to the state, and unquestionably should be utilized in a manner which will secure the utmost practicable advantage to the community. There is every reason why they should not be appropriated in perpetuity either by individuals or corporations. In permitting their appropriation and use for a limited period, the state undoubtedly should obtain the best terms possible, but the fact that prompt utilization means not only a saving of coal resources but a reduction in cost of manufacture and transportation is a consideration of the utmost weight. As compared with the direct revenue which can be expected to result from levying a direct tax upon water powers, this consideration, from a broad economic standpoint, is in all probability controlling. Doubtless the state *can* tax water powers and *can* devote the proceeds of such tax to any special purpose which it may elect; for example, the construction of inland waterways, as has been proposed; but correct determination of the wisdom or folly of such an arrangement requires careful consideration and at least approximate knowledge of the quantitative values of the economic results to be expected.

In a short speech before the Conference of Governors at the White House in May, 1908, referring to water powers, President Roosevelt said:

> My position has been simply that where a privilege, which may be of untold value in the future to the private individuals granted it, is asked from the Federal Government, that the Federal Government shall put on the grant a condition that it shall not be a grant in perpetuity. Make the term long enough so that the corporation shall have an ample material reward. The corporation deserves it. Give an ample reward to the captain of industry but not an indeterminate reward. Put in a provision that will enable our children at the end of a certain specified period to say what in their judgment should be done with that great natural value which is of use to the grantee only because the people as a whole allow him to use it. It is eminently right that he should be allowed to make ample profit from his development of it but make him pay something for the privilege, and make the grant for a fixed period, so that when the conditions change, as in all probability they will change, our children—the Nation of the future—shall have the right to determine the conditions under which that privilege shall then be enjoyed.

With the ideas thus vigorously expressed, every good American citizen must be in sympathy. To the admirable exposition of principles included in the preliminary report of the Inland Waterways Commission, dated February 26, 1908, few engineers will take exception. But the attitude of some of the speakers at the recent Conservation Conference in Washington, upon the occasion of the second gathering of the governors of the states, clearly evidenced a disposition to beg one of the fundamental questions which arises at the very threshold of consideration of the utilization of our streams; namely, the question of the real economic value of inland waterways. The minds of some who are taking an active part in the discussion of this great economic question apparently start with two assumptions: 1. That the economic value of a vast system of inland waterways is admittedly so great as to justify practically any expenditure in its development. 2. That the water powers upon our streams are inexhaustible mines of wealth capable of yielding, under a general system of taxation, large revenues. From these premises, the conclusion that water powers should be taxed to pay for waterways is easily deduced.

To the engineer it is evident at once that before any conclusion, involving expenditure of large amounts either of public money or private capital is agreed to, both premises upon which that conclusion is based should be critically examined.

I do not propose in this paper to attempt anything purporting to be an exhaustive discussion of this complex subject. Personally I am frank to admit I have found it impossible from my present knowledge to form definite and final opinions in respect of some of its phases. If our national engineering societies, during the coming year, will secure from their members best qualified by special knowledge to supply pertinent facts and suggestions, carefully considered papers discussing the comparative economics of transportation by rail and by inland waterways, much light will be thrown upon this very important and far-reaching question. At present data apparently essential to well-grounded judgment have not been collected and compared in a manner to justify formation of definite and final opinions which can be expressed in precise terms, opinions which may be expected to stand the test of time.

In calling attention to certain considerations which apparently tend to controvert the present popular impression that a radical improvement and extension of our inland waterways is the natural and proper solution of the great problem of freight transportation, I trust it will be understood that I am not approaching the subject from the standpoint of one whose interests are identified with railways. Such is not the case. The electrical engineer has everything to gain and probably nothing to lose from a policy which during the next 10 years may result in the appropriation of from $50,000,000 to $100,000,000 per annum for the improvement of our waterways and development of our water powers. An engineer's first duty in a case of this kind is to bring any special knowledge which he possesses to bear upon the economic problem presented, to form and to state his opinions absolutely without bias. In our offices and in the field we may be retained properly to represent this or that special interest, but on the floors of our engineering societies our proper attitude is that of the man of science interested solely in the facts, their causes, relations, and consequences.

In considering the proposition to impose a tax upon water powers and devote the proceeds of this tax to the construction of a system of inland waterways, it is clear that the first effect of such a tax would be to retard the development of water powers unless some compensating advantage were offered. It is also evident that such a tax would operate indirectly to stimulate the consumption of coal, and that if it be decided that we can afford to tax manufacturers indirectly in order to improve transportation facilities it would be wiser, from the standpoint of conservation of our power resources, to impose a tax upon coal used for power purposes. A tax of $3.00 per horse power

($4.00 per kilowatt) per annum is equivalent to a tax of 40c. a ton (2000 lb.) on coal used for power purposes in manufacturing, if we assume that 5 lb. of coal per h.p.-hr. are used. A proposal to impose any such tax on coal used for power purposes and use the proceeds for the construction of inland waterways probably would command little influential support, and yet a similar proposal, as applied to water powers, has received weighty endorsement and apparently is highly approved by those who are especially interested in the development and extension of inland waterways.

In the report of " The Inland Waterways Commission, acting as the Section of Waters of the National Conservation Committee before the last Joint Conservation Conference," I find the following referring to the uses of water power in our streams:

> The paramount use should be that of water supply; next should follow navigation in humid regions and irrigation in arid regions. The development of power on the navigable and source streams should be kept subordinate to the primary and secondary uses of the waters; though other things equal, the development of power should be encouraged, not only to reduce the drain on other resources, but because properly designed reservoirs and power plants retard the run-off and so aid in the control of the streams for navigation and other uses.

It would be interesting to know how the conclusion has been reached that in humid regions the development of power on our streams is less important than the improvement of navigation. To one familiar, for example, with power developments in the cotton mill district of the Carolinas, and with the character of the streams there utilized so extensively and with such vast advantage to the community for power purposes, the idea that any conceivable use of these streams for purposes of navigation can be comparable to their value as producers of power is to say the least highly improbable.

Obviously before any such general policy as that recommended is adopted, we should have assurance that the imposition of such a tax will not cost the community more than the resulting improvement of transportation facilities is worth. Cheap power is a factor of great importance, both in manufacturing and transportation. According to the census of manufactures taken in 1905, the gross output of our factories and mills had a value of $16,866,706,985. This product represented $1,152.00 per horse power installed. The wages paid amounted to $248.00 per horse power installed.

In the same year, the aggregate gross receipts of our railways were $2,325,765,167, or about 14 per cent of the value of manufactured products.

The object sought in constructing inland waterways is reduction in cost of transportation. The proposal to impose a tax which will operate to increase costs, in a business amounting to nearly $17,000,000,000 per annum, in order to attain an undefined advantage in reduction of cost in a business of less than one-seventh that amount calls for something further in the way of analysis than has yet come under my observation in this connection. The fact that manufacturing costs in America are in general much higher than in Europe, while our cost of transportation per ton-mile is now materially lower than can be found elsewhere, emphasizes the impression which results from a moment's consideration of the respective gross volumes of business in these allied fields of industry.

It would be impossible to suggest a more fruitful subject for unprejudiced analysis and illuminating exposition by competent members of our national engineering societies, in the immediate future, than the comparative economic advantages of railways and inland waterways. Facts in this field are urgently needed, and should be supplied before public sentiment, unenlightened by unbiased competent advice, and influenced, perhaps, by prejudice and the clamor of local interests, shall crystallize in legislative enactment or executive rulings. Within the last two years, my firm, in considering problems presented by the substitution of electricity for steam in railway operation, has carefully studied the cost of operation of steam railways in the United States, using as the basis of this investigation not only the valuable reports of the Interstate Commerce Commission but also detailed operating cost-sheets confidentially furnished for the purpose by a number of the most important railways in the country. It also happens that within the same period we have had occasion to determine with great care the actual cost of operation of one important canal system, and in this connection have secured considerable information bearing upon the general question of the economics of canal transportation. The conclusions which we have reached as a result of these comparative investigations do not support broadly and without material qualifications the popular impression that transportation of freight by inland waterways, in general, is less expensive than transportation by railways.

In engineering matters, general statements almost invariably are subject to exceptions and I am not prepared to assert broadly that the construction of canals for transportation purposes is a mistake. I do assert, however, that in the majority of specific instances that have come under my observation the facts are far from justifying, from an economic standpoint, a propaganda aiming at the development of a general system of inland waterways beyond what may be attained by reasonable improvement of the channels of navigable streams with such comparatively short inter-connecting canals as may beyond reasonable doubt be justified by the results attained.

As regards the proposed " concurrent development of the streams and their sources for every useful purpose to which they may be put ", as it is stated in the " declaration of principles " of the recent North American Conservation Conference, all engineers will agree that each stream should be studied with reference to its possibilities " for domestic and municipal supply, irrigation, navigation and power as inter-related public uses." But the development of a plan economically sound calls for unbiased consideration and fairly accurate knowledge of the economic value to the community of the resulting improvement of the stream regarded as a waterway for transportation. Obviously if we begin by assuming that because freight is carried across the Atlantic or through the Great Lakes at less cost per ton mile than it is carried by our railways, an increase in the depth of channel or improved regularity of flow of any given inland stream will secure corresponding results, we shall be misled and expenditures based upon any such assumption will be wholly or largely wasted. Each case should be studied and competently studied on its own merits. To tax water powers for the purpose of providing free waterways, from a broad economic standpoint, is a policy which, before adoption, should be compared carefully with the plan of imposing tolls upon all users of inland waterways and using the proceeds to develop water powers and secure cheaper power for our manufacturing industries.

The declaration of principles agreed upon by the recent North American Conservation Conference makes the following statement:

> We recognize the waters as a primary resource, and we regard their use for domestic and municipal supply, irrigation, navigation, and power, as interrelated public uses, and properly subject to public control. We, therefore, favor the complete and concurrent development of the streams and their sources for every useful purpose to which they may be put.

In the preliminary report of the Inland Waterways Commission, dated February 26, 1908, I find the following:

> While navigation of the inland waterways declined with the increase in rail transportation during the later decades of the past century, it has become clear that the time is at hand for restoring and developing such inland navigation and water transportation as upon expert examination may *appear to confer a benefit commensurate with the cost*, to be utilized both independently and as a necessary adjunct to rail transportation. [The italics are mine].

The fundamental facts here set forth will receive the unanimous and enthusiastic endorsement of the entire engineering profession. In determining, however, how the admirable and vastly important objects in view are to be attained, every engineer should use his best endeavors to prevent fundamental and far-reaching mistakes which easily may result from action based upon insufficient or inaccurate knowledge.

DISCUSSION ON "ELECTRICITY AND THE CONSERVATION OF ENERGY." NEW YORK, MARCH 24, 1909

(Subject to final revision for the Transactions.)

John Coffee Hays (by letter): In arousing public interest in the conservation of our natural resources the impression has been generally given in discussions and newspapers and magazine articles, that there was a very much larger waste going on than actually exists, and it would seem therefore that the time is now ripe for the engineers to discuss the different points of the question more in detail, and show what work has already been done in the direction of conservation, and what in their opinion should be done in the future toward the use of our resources in the most economical manner. From the very nature of the work, engineering is more closely connected with the conservation of resources than is any other profession, and the engineer should lend every effort in his power to the general education of the public in this respect, and should discuss the various points of the subject practically and forcibly in line with his convictions and experience.

In the papers presented before the joint meeting of the four largest engineering societies on the evening of March 24th, it was clearly shown that very great work had been done in the past generation in respect to the economical use of our natural resources, and the strong paper presented by Mr. Lewis B. Stillwell clearly pointed out the large part that electricity was accomplishing in this direction, and it is in line with this paper that I wish to discuss briefly the position of the water-power developments in the far West.

The writer in his connection as consulting engineer to several of the largest hydro-electric projects of California has had the opportunity to make a close study of the subject from all sides, and particularly as to the policy of the federal government in connection with power projects in the forest reserves and national parks of California, and the effect that the present policy of the Department of the Interior has on the development of these projects which comprise practically all of the present available undeveloped water-powers in the state.

The water-powers have probably attracted more public attention in the last two years than any of the other natural resources, as they are the only ones which will not be exhausted by use, and this fact makes it natural for the layman to assume that "the great water-power monopoly" which the press and the magazines frequently refer to, is a grave calamity facing the public, especially when the high officials of our government express similar opinions. The writer, of course, agrees that if in the distant future a monopoly were formed comprising all of the water-power in California, and providing that such a monopoly could be formed over which the federal government and the local authorities had no control, that it would be detrimental to the public interests when the natural supply of fuel was exhausted, but even under the present laws of the state it does not seem possible that any extortion could be practised even were the water-power business controlled by one company, for the governing body of every community, be they supervisors, or city trustees, have the power to regulate the rates of any water-power or any other public service corporation.

It is not my object to discuss whether or not a water-power monopoly threatens the people of California, but rather the point as to whether the present policy of the government is beneficial in checking a monopoly, or detrimental, by preventing the development of one inexhaustible natural resource and therefore necessitating a greater use of our exhaustible resources, such as oil and coal.

It should be clearly understood that the state and not the federal government owns the water in all of the streams available for power developments in California, and that the state has enacted laws which clearly set forth the manner in which this water is to be diverted and used. In the case of the forest reserves and the national parks the government simply owns the land through which the streams flow, and therefore the only way that the government can control this development, is due to its ownership of the lands on which the conduits and power stations must be constructed. Where land along a stream is held by an individual, it may be condemned by a power company, and the owner receives compensation only to the amount of the actual damage done his property, and as the land along these streams is useful only for grazing purposes, the damage is very slight—not greater than a few dollars per acre for a right-of-way 50 or 100 feet wide, the entire length of the conduit, and in fact, a private owner often grants this right-of-way to the power company free of charge. The riparian right which entitles the land owner to the amount of water necessary for the irrigation of his lands, is his only other right, but in the mountain districts, owing to the character of the land, there are very few cases where they are fit for agricultural purposes and therefore irrigation is not required.

The primary object of the forest reserves was for the protection of the timber thereon, and therefore should include only timber lands. This being the case, the majority of available power sites, which are at present embraced in the forest reserves, should not be affected, as the land on which these sites are located is in most cases below the timber line, and would consequently be outside of the reserves. However, the present forest reserves take in complete watersheds from the highest peaks, several thousand feet above the timber line, to the edge of the valleys several thousand feet below the line of the marketable timber, as in these lower altitudes only the small trees and brush are native. It would appear therefore that the boundaries of the forest reserves were set with the idea of controlling the water-powers. The forest department makes a point that owing to the protection of the forest they maintain the streamflow and therefore should be entitled to regulate the use of the water in the streams so far as the streams lie within the reservation. It is a generally accepted fact that the forests act as natural reservoirs in the regulation of streams, and this no doubt is correct in respect to the Eastern states where the mountains are comparatively low and heavily timbered, but in the far West we have a rather different condition as far as the water-power developments are concerned, and I wish to venture the opinion that the forests on certain watersheds in parts of the Sierra Nevada mountains are of comparatively little practical advantage to the power company, for in these cases the timber line is far below the crest of the range, and it is the melting snow on these barren rocky slopes above the timber line which gives us the water during the lowest water period of the year, there being very little run-off from the forest portion during this time.

It is the aim of the federal government, the state and in fact all conservative men connected with water-power development to discourage the practice of irresponsible parties filing an appropriation notice on a stream, and then holding the right for speculative purposes. Under the state law, after posting a notice on the stream and filing a copy of same, the appropriator must within 60 days of the time of filing his notice begin work and continuously prosecute it to completion with due diligence. Where the stream lies within a forest reserve the state law has been amended to the effect that within 60 days after the filing of the notice, work must be started in the form of a survey for the preparation of an application to the Department of the Interior, and after receiving a permit from the Department of the Interior, work must be started within 60 days, as above, and pushed to completion within the time specified in the permit. The Department of the Interior allows one year for the making of the survey and the filing of the application, and as a considerable amount of time is necessary for investigating the project before an application is granted, it can mean from 18 months to two years before actual construction work is necessary, and if it is a case of speculation, the speculator has really more time and is in a more comfortable position when his appropriation lies within the reserve than when it lies without. In the investigation of the Department of the Interior before granting a permit, it is the aim to ascertain the feasibility of the scheme as well as the financial responsibility of the appropriator, and were this investigation pursued efficiently and with a view of developing a watershed of the highest efficiency, it would no doubt be of great advantage, but at present the Department is not in position to do this, and the question of feasibility and financial responsibility is left greatly to the judgment of the local forest ranger who is absolutely incompetent to judge of these matters, owing to the fact that the majority of these rangers have been born and raised in the mountain sections, and while as a rule most admirably fitted for their position as far as the guarding and protecting of the forests are concerned, they have neither the education nor experience which would enable them to pass intelligently on a power project or anything relating thereto. While in the case of the state's requirements, the diligent prosecution of the work until completion, is often interpreted to mean a very small amount of work by the speculator, it does not seem that the government requirements have bettered the matter to any extent, and it would seem that the state at least had the advantage of simplicity, for should the appropriator not prosecute work with diligence, and be in a position to prove that he had lived up to the requirements, he is in constant danger of having some one else make an identical filing, and push the construction of a plant to completion, thereby leaving him without anything; for no rights of any kind are obtained under the state law until the water is actually diverted and used, when the right is then acquired and dates back to the time of filing the notice of appropriation. While it is held by most of the water-power companies and many authorities, that the government has no right to control the water-powers within the reserves simply because it has acquired land, it is my opinion that were the regulations and requirements of the forest department at all reasonable, that they would meet with very little opposition from the power companies, and it is my further opinion that practically all of the opposition is caused by the revokable form of permit, and the so-called conservation charge made for same. As far as financing property and affording any protection to the stockholders of the power company, a form of permit which is revokable at the discretion of the Secretary of the Interior is absolutely worthless, especially when some of the absurd conditions which are imposed in the present form of permit are taken into consideration, for the permits as now granted, mean that if at any time, a company has not in the opinion of the Secretary of the Interior, lived up to the conditions imposed, and the rules and regulations of the department, the permit may be forfeited, and a plant representing the investment of millions of dollars, confiscated by the government and entirely lost to the power company. One of the absurd clauses in the permit is to the effect that the company shall not break any of the game laws, which means that should an employee, no matter in what capacity, catch a fish, or shoot a deer out of season, the company would be liable, and its permit could consequently be revoked. It is of course impossible for a company to be responsible for its men to this extent, and it is further absurd when it is considered that the breaking of a game law is a state, and not a federal government offense, whether it be within a forest reserve or without.

As regards the conservation charge or the tax on the permit, this, while comparatively small at present, is also subject to change at the discretion of the Secretary of the Interior within specified but broad limits, and aside from this it is open to considerable question as to whether or not the government has any right legally (and it is manifest that it has no right morally) to collect this tax, for by so doing it forces the power company to charge a higher rate for power, thereby placing it in the position of tax collector for the government to collect from the people of a comparatively small community, thereby throwing an additional tax on the citizens served. There has been considerable discussion as to what use this money would be put, and it is generally considered that it might be used for the improvement of inland waterways or to apply toward the expenses of maintaining the forest reserves. Mr. Stillwell, in his paper discussed the matter of taxing water-powers for the improvement of the inland waterways, and I will therefore pass over this point. However, as regards the application of this money toward the maintenance of the forest reserves it would appear manifestly unjust from the simple fact that the forest reserves are created and controlled by the federal government and any expenses in the maintenance of them should be borne by all of the people of the United States, and not by the people of a comparatively small community who derive little, if any benefit from them. It is also impossible to state any fair rate of taxation which would be applicable to all water-powers, as each power is peculiar to itself, and the cost of construction varies within wide limits, whereas the market value for power is practically the same, so that a tax which would not be felt by one company might be ruinous to another.

This discussion is not intended in any way as an attack on the principle of government regulation of water-powers, and were this an entirely new industry in a new country having no laws governing the streams, or should the title to the waters of the streams pass to the government with the lands, it would be an entirely different proposition, and might be handled by the government to advantage. The fact is, however, that this is not a new industry, and that well-defined state laws have been enacted and in force for years, and when it is taken further into consideration that the government lays absolutely no claim to the waters of the streams, it would seem impracticable and extremely unjust for the government in the form of a landowner to stifle the development of one of our most important industries, and the present policies of the Department of the Interior can have no other effect.

There is of course, a popular feeling and a natural one, that perpetual water rights should not be held by any individual or corporation for power purposes, still the state laws provide that this may be done, and it would seem that if a time and limit were to be put on a water-power, the only way to accomplish it would be by the changing of the state law and not by revokable permit. A water-power is of necessity a monopoly to a certain extent, that is to the extent that a street railroad franchise is a monopoly on the street during the life of its franchise. The power company's monopoly is confined simply to its position on the river and its right to use a certain amount, or all, of the water for power purposes at this point, but these rights do not give it a monopoly of the market, for should it charge its consumers a high rate for power it would immediately court competition, and a power company on an entirely different river, could extend transmission lines into the territory served, for it must be remembered that electric power is being commercially transmitted hundreds of miles with an extremely small loss of energy.

The present condition could be relieved to a great extent, however, by a very simple means; that is by the granting of an irrevokable permit by the Department of the Interior to the water-power company for a certain definite period, and making a definite provision for the disposal of the property at the expiration of this grant. All the absurd conditions of the present form of permit should be omitted, and if there must be a conservation charge, a definite sum should be set for the entire period. In this way the power company would know exactly the position it was in, and the conditions which it would be necessary to meet. As to the disposition of the property at the expiration of the permit, it should be decided whether or not the power company should simply give up all its property at this time, whether it would be taken in by the government at a predetermined cost, or whether it would be sold at public auction. If the power company were to release all rights at the end of the period, it would of course necessitate its laying aside a sinking fund to pay for the installation, which would throw a burden on the consumer, in that it would necessarily increase the cost of the power reduction.

As to the government control, during the term of the grant, to prevent extortion by the company, I am of the opinion that very few people aside from the government officials and magazine writers consider this seriously, as the state has laws which amply protect citizens from any extortion by power companies, and the government should therefore let the power company entirely alone during the term of its grant. At the expiration of the grant, the property would come again under the control of the government for its disposal, when it might make any changes which in the meantime had proved would be of advantage. In making any regulations, the fact cannot be overlooked that some incentive must be held out to capital in order that this power be developed, and these absurd difficulties which have been placed in the way of power companies by the Department of the Interior must be removed, before a hydro-electric project is considered in any other way than a most undesirable investment, as is the case to-day.

While it is the general impression that a monopoly of any kind is not beneficial to a community, it has also been proved that a large producer may operate more economically than a small one, and this point is particularly noticeable in the development of the water-power in the far West, owing to the great distance of markets, and the advantage of combining the output of several hydro-electric power stations and distributing them along the same transmission lines and so placing the power stations that the available water may be used several times, and in a more economical manner. It does not follow that all of the water-powers in the state should be combined, but the writer believes it is absolutely necessary for an economical development of any stream, that all power installations in the watershed be under one management, so that the entire watershed may be treated as a unit and worked to its best advantage. In a case that I have in mind, approximately, 50 per cent more power could be developed from the watershed were it held by one company than could be developed by two rival companies. This is the case where the storage reservoir capacity would be on the small tributaries of the main river. With a generating station situated on the main river, the water from these tributaries could be stored during the high water season, when there will be plenty of water in the main river to operate the plant, and during the low water season the flow of the main river could be reinforced with the stored water in the reservoir, thereby keeping the plant up to full capacity. Now assume that one company owns a generating station on the main river and a rival company holds the reservoir sites on a tributary, and that no reservoir sites are available on the main river; the plant being supplied on the main river would of necessity be installed for a capacity equal to the minimum flow of the river during the low water season, while the plant on the tributary would be installed for the average yearly flow of that stream, as both stations must be operated at full capacity for 365 days a year. When it is taken into consideration that the minimum flow of the rivers of central California is not over 5 to 10 per cent of the average yearly flow, it would be clearly seen that without storage reservoirs there would be an enormous amount of water going to waste during the high water season. The condition above assumed is the rule rather than the exception, in that it is a difficult matter to find storage reservoir sites on the large streams, and when available they are usually very expensive to develop, whereas on the smaller tributaries there are often mountain meadows, lakes, etc., which may be more practically converted into reservoirs by the construction of comparatively cheap dams, where almost the entire run-off of the tributary may be stored during each year, to be used later in reinforcing the main stream. The construction of reservoirs for water-power purposes is also a great advantage to the country in the valleys, as it reduces the water in flood periods and conserves it for use for irrigation later in the season when it is greatly needed, and this point alone should serve to gain support for a water-power development. Unless each watershed is taken as a whole, and studied with a view to the most economical development, it is apparent that a great waste would ensue which would be almost permanent, as a properly installed plant represents a great deal of invested capital, and anyone would seriously hesitate before abandoning it, even for the purpose of effecting a more economical arrangement. As to the position the existing water-power companies hold to-day, it would be gathered from the sensational utterances of the press and the skilfully written articles in some of the magazines (which however are not always based on facts) that even to-day a water-power is a monopoly, and that the people are suffering through them. It would be well, therefore, to look at a little of the work which has been accomplished by the development of some of our western water-powers, and the case I will cite, being a power company supplying power to a strictly agricultural community in the San Joaquin valley, is I think one of the best examples of the conservation of a natural resource that I have encountered. This company began operation about ten years ago, and its territory comprises a section of approximately one million and a quarter acres of land. At that time approximately 90,000 acres of the land were under irrigation, and all of the water in the natural streams was diverted and used, so that the remaining land which was most suitable for the raising of high-class products, when irrigated, was of necessity undeveloped owing to the lack of water, and was used only for the growing of grain and for grazing purposes. About this time it was discovered that approximately 150,000 acres of this land lying along the foot-hills was exceptionally well adapted for the raising of oranges and other citrus fruits, and as the profits on these products are extremely large, endeavors were made to irrigate these lands by pumping water from wells. Gasoline and steam engines were used for pumping, but owing to the unreliability and cost of operating these engines by unskilled men very little was done. With the advent of electric power the country developed rapidly, and this rapid development continues. There are at present over 20,000 acres of land planted to these products, irrigated by water pumped from wells by electric motors, and the gas engine and steam engine have completely disappeared from the field. The value of the land which at the advent of electricity was from $2 to $10 per acre has increased to as high as $400 per acre, and the orange grower makes an average annual net profit of approximately $250 per acre. This $250 is interest on an investment of approximately $500 including the land at $100. per acre, the remainder being spent in planting and caring for his orchard for the first five years, when it comes into bearing. The irrigation which makes all of this possible, amounts on an average to about $10 an acre per year for the power used, as the price charged is $50 per horse power per year, and one horse power used in this way will irrigate on an average five acres. It may be farther noted that the cost of harvesting, raising and shipping the crop amounts to from $300 to $500 an acre, when the net is $250, and it is therefore apparent that the power charge is an insignificant item of the expense, and that the consumer is not being very badly robbed by the power company, magazine articles to the contrary notwithstanding. The rate of $50 per horse power per year is often compared with such prices as are charged at Niagara where thousands of horse power are sold to one consumer, whereas in this case the average size motor used is 7½ horse power. In a plant such as Niagara the installation is comparatively cheap owing to the large units, the short conduits, and the accessibility of the plant, but in the western plant mentioned, the output is comparatively small, and the plant is located many miles from a railroad, requiring the transportation of all machinery and material over rough mountain roads at great expense. The conduits are long, and constructed along steep mountain sides, thereby making the expense of hauling and hoisting, one of the largest items of construction. The investment in distributing lines alone, due to the marketing of the power in small quantities over a wide area amounts to approximately half as much as the cost of the rest of the plant. This illustrates also the necessity of treating each water-power separately when considering profit on prices charged, as all of the water-powers which the writer has investigated operate under entirely different conditions, and it requires a very thorough knowledge of any plant to be able to discuss it, or the rate of charges, with any degree of exactness. This knowledge of the property can be gained only by an examination in the field. The plant described operates on rivers, the waters of which are used exclusively for irrigation. One miner's inch of water will irrigate about 5 acres in this section. The water-power company uses the water in the mountains and turns it back into the stream, whence it flows out to the valley and is used for irrigation, while the power house transforms the energy of this water without diminishing it, and also sends to the valley in the form of an electric current over wires, energy which is used for the pumping of additional water from the underground reservoirs, and therefore is another irrigation project. In the above mentioned system approximately 100 second-feet are used and with this is generated approximately 7,000 h.p. which may be delivered to the pumping plants. Of this 100 second-feet a large proportion is of course lost in evaporation, seepage, etc., before it is applied to the land, but assuming that it were all delivered and placed on the land for irrigation it would be capable of irrigating about 20,000 acres, but in passing through the power-house it also generates enough current to irrigate approximately 35,000 acres by water pumped from wells. It can be seen that this is indeed conservation in its highest form.

DISCUSSION ON "THE LOG OF THE NEW HAVEN ELECTRIFICATION." NEW YORK, DECEMBER 11, 1908

(Subject to final revision for the Transactions.)

President Ferguson: The American Institute of Electrical Engineers is to be congratulated in having as a member, a man who is so willing to come forward and frankly state the actual experience he has had in the construction and operation of so new, so important, and so untried an undertaking. I think we owe it to him to show our appreciation of the work he has done by giving full discussion to his paper: first, as to the major and minor faults that have been experienced in the system and of the corrections that have so far been applied, and of the possible corrections that may come in the future; secondly, as to whether this system, as designed and constructed will fill the requirements of the entire electrification of the road from New York to Boston, as we understand is contemplated by the railroad; thirdly, as to whether this system as designed and constructed will fill the requirements of the electrification of terminals in our large cities, taking into consideration the handling of the through and suburban passenger traffic as well as the switching and hauling of the freight traffic.

Calvert Townley: I am strongly impressed by the extremely radical treatment which the author has given to his subject. Abandoning the usual course of emphasizing the advantages of the system adopted, he has passed over them with but scant mention, and has given in minute detail a list of the troubles encountered. The magnitude of the project itself, the amount of advertising which it has had, and the fact that it has been attacked continuously, not to say viciously, by those who disagreed with the plans adopted, or perhaps were interested in seeing them fail, demonstrates the author's courage in handling the subject as he has, but also emphasizes the radical character of his treatment. What the designing engineer wants to know; what the constructing and the operating engineer wants to know—what indeed everybody wants to know who is undertaking a new project is, what troubles and difficulties he is likely to meet, and how can they be overcome. The advantages of one plan or another, the perfect features, so to speak, will, in great measure, take care of themselves. Therefore, where a system is already playing so important a part in the railroad world as is the single-phase system—destined to play a much greater part in the future—we are particularly fortunate in having a member who can present so full a log of its application to so important a project, and of its troubles and their remedies, as Mr. Murray has done in this paper.

It is to be noted that Mr. Murray has omitted the customary statement of conclusions usually drawn from the facts furnished in a paper. The conclusions, however, are none the less clearly indicated, even though they may not be stated. Those which seem to stand forth are:

1. This system was put in without any previous similar installation to pattern after.

2. Several of its fundamental features were either entirely new or had so new an application, that their previous use was not much of a guide.

3. Sundry and various defects developed as the installation progressed, resulting in interruptions to the service.

4. These defects have practically all been remedied, certain other improvements have been made, and

5. That now, five months after the complete substitution of electricity for steam, and while some of the improvements have still to be completed, the system has been demonstrated to be successful, and well adapted to the service for which it was designed. As an interesting fact it may be here noted, that at the present time the electric service is less subject to interruption than was the steam service which it has replaced.

From an engineering standpoint it may help us to realize the nature of the project undertaken, if I recapitulate some of the pioneer features that were included in this installation. For example: it is the first installation to generate single-phase current in large units at a fairly high electromotive force with a dead ground on one side of the generating system; it is the first installation to adopt, though not the first system to put into operation, the 11,000-volt, alternating-current trolley, with the rail return, without any transformer, converter, or other substation appliance whatever between the generator and the locomotive itself; it is the first alternating-current system to handle 800-ton trains at 60 miles an hour; it is the first installation to use an alternating current, gearless, 25-cycle motor (it also uses much the larger motors of this type); it is the first installation to adopt a locomotive unit designed to fit the normal, instead of the heaviest, train service, and to take advantage of the multiple-unit feature of operating two or more locomotives together, when heavier trains require it.

In my opinion, the one radical thing that was done wrong in the New Haven electrification, and which was really at the bottom of the major part of the difficulties that have been encountered, is that the electrification was not begun soon enough. It is undoubtedly true that had more time been allowed for attention to the minor details of the equipment, and could work that had to be done under great pressure have taken its normal course, many of the minor troubles which can be traced to these facts would never have existed, and, furthermore, had there been time for a reasonable operating tryout, very many of the defects which have caused delays to service, would have been detected and remedied during the trying out period instead of in practical service.

In referring to the log of operation, Mr. Murray says, "We are not proud of it." I am not one who feels that any apology for the results obtained is in order. The combination of an installation embodying so many new features and an insufficient time in which to overcome difficulties, was recognized in the beginning, and it was felt that a superior plan, handicapped with some temporary troubles, was better than an inferior plan with fewer threatened temporary troubles, but many permanent disabilities.

I should feel that I had been remiss if I closed my remarks without paying tribute to the Westinghouse engineers for their part in this project. Their development of the necessary machinery and appliances alone has made the project possible. Without them this single-phase installation could not have been successful. They are rightfully entitled to a frank acknowledgment of their continued cheerful, resourceful, and courageous coöperation through the entire progress of this enterprise.

The keystone of the system is the locomotive. Without the single-phase, alternating-current motor the whole plan would become impossible. No one doubts but that a power house can be built successfully to generate current, and that a line can be constructed successfully to transmit single-phase alternating current at any reasonable voltage and over a wide range of quantities; but it was not until the single-phase motor was developed, that the simplification possible with this form of traction could be even considered. To me, therefore, the most interesting part of this paper relates to the performance of the locomotives. The log of operation showing delays, etc., is interesting, but I do not regard it as of particular importance from an engineering standpoint, as a hot bearing on a blower motor would as quickly bring about a delay to service as an entire breakdown of the locomotive itself. Some troubles with the minor parts may always be expected at the start in any large installation, but if the fundamentals are not impeached, success is not in jeopardy.

A study of the list of changes that were made in the locomotive originally furnished, and enumerated by Mr. Murray, discloses the interesting fact that while there were a number of electrical difficulties, a very large per cent of the changes made were mechanical, not only mechanical changes to mechanical features, but also mechanical changes to electrical features, most of the latter being on the minor parts of the equipment, which, naturally, had to receive the least attention when time was pressing. With the principal elements of the locomotive design; namely, the large gearless, 25-cycle motors, there has been practically no trouble. Their performance as to torque, commutation, and capacity has been most gratifying. It was soon demonstrated, in fact, that the motors and transformers had capacity for service in excess of that called for by their guarantees, and investigation showed that by somewhat increasing the capacity of some of the minor parts of the locomotive equipment, a machine of materially greater duty would be provided. For this reason several changes were made in the locomotive details, not primarily to correct defects, but so to increase the capacity of the parts modified as to provide an excess locomotive capacity. Mr. Murray mentions but briefly a feature of locomotive design, which from the standpoint of dollars and cents value to the operating road, deserves a place in the front rank. Perhaps he has passed by this feature so readily because his mind has been bent on telling of troubles, and this feature has caused no trouble. I refer to the flexible drive whereby the armature of the gearless motor is wholly supported on, and exerts its driving power through a set of spirally concentric springs. Trackmen have frequently been appalled because electric locomotives are so much harder on track than steam locomotives of even greater weight, and it has now come to be a generally accepted conclusion that this fact is due to increased impact because the armature dead-weight is supported without cushion, rigidly on the axle. The impact due to this additional dead-weight is something astounding. In the New Haven locomotives, the method of mounting the armatures, obtaining the cushioned effect, exerting the full driving power of the motors, and compensating for the so-called varying torque thereof, has been successfully accomplished in a way never before tried. The results in improved track maintenance cannot fail to be of far-reaching consequence.

Similarly with the line—while insulation troubles have been manifest, due first, to low bridge-clearances, and secondly to steam locomotive stack discharges, the principal overhead difficulties have been mechanical; that is, the mechanical wear on the trolley wire and too great rigidity in its method of support. The serious line difficulty to which Mr. Murray refers, resulted from a combination of these mechanical troubles. They were not discovered for the first time in May, but had been manifest for a considerable period, and were being carefully studied. The extent of the trouble, however, could only be demonstrated by an extended tryout, because it was affected so vitally by the amount of stack discharge and by the rapidity with which the pantagraph shoes traveled over the trolley wire at high speeds. The addition of a steel wire flexibly suspended from the copper conducting wire, a wire to take the wear, was, however, the solution. With it there disappeared the last threatening difficulty that need cause any apprehension.

B. G. Lamme: Though I have been more or less intimately interested in all of the problems in this New Haven electrification, there were two parts of the total equipment to which I gave a great deal of my personal attention, namely, the design of the alternating-current generators in the power house and the main motors on the locomotive. The popular opinion, even among designers, was that the motor was by far the most difficult problem of the two, considering that it was the first large gearless single-phase motor constructed for commercial service. As for the generators, one engineer has said "anyone can build generators." However, from my own point of view, since borne out in practice, the design of the motors was a comparatively simple problem compared with that of the generators.

Considering first the main motors. There are 41 locomotives on this road, each with four gearless motors, wound for both direct-current and single-phase operation. I do not intend to discuss the design of these motors, but simply to indicate some of the records that have been made. In the motors themselves there were two points that were generally looked upon as sources of weakness; namely, the commutation (and life of the commutator) when operated on alternating current, and the use of preventive leads (or so-called "resistance leads"), between the armature winding proper, and the commutator. Many people have sounded a warning in regard to the dangers from the use of these preventive leads. It was also assumed that there would necessarily be severe sparking at the commutators of these motors, which was bound to injure them in a relatively short time. Let us look at the record on these two points:

As I stated, there are 164 main motors. The first equipment was put into commercial service the latter part of July 1907, and the last equipment, being part of the order of six, mentioned by Mr. Murray, was put in operation about July 1908. The records show that the total of 164 motors have averaged slightly over 40,000 miles each since being put in operation, the minimum mileage for any one motor being approximately 28,000. A range from 30,000 to 50,000 miles will cover the record of most of these motors. With the above mileage, the commutators of these motors are all in excellent condition, having a good polish and showing but relatively little wear. Virtually all of the motors on the first 35 locomotives have been dismantled at some time or other, for the causes mentioned in Mr. Murray's list of changes. At such times the commutators of these motors were cleaned up slightly, just as any other part of the motor would be cleaned up. The commutators were not turned unless they showed evidence of mechanical injury, generally from some cause external to the commutator itself. However, in commercial service these commutators have required no attention, and, as far as I could determine, none of them has ever been sand-papered while in service. At the present rate of wear on these commutators, there appears to be 15 to 20 years' life in each one of them. As there is but relatively little sparking, even when developing two or two and a-half times full-load torque, there is no real reason why these commutators should not make such good records.

Considering next the injuries to the motor. Mr. Murray's tables show reference here and there to motor injury, without stating just what kind of injury is meant. Simply to state that a motor is injured, without saying what part is injured, may give a wrong impression. It is generally considered, and correctly so, that an injury to the armature of a motor is a much more serious condition than an injury to the field or the connections. The records of the New Haven installation show that the injuries to the armature represent only a small percentage of the total injuries. In fact, the few damages to the armature have been largely from external causes, foreign substances, such as bolts, tools, water, etc., getting into the motor, or from unsoldering at the commutator or at the rear end, due to the extreme overloading, which has occurred in a few instances, as when pulling a heavy train with one locomotive with one pair of motors cut out. In a few instances these damages have resulted in an actual burn-out of a section of the armature, necessitating part rewinding.

In such cases I have been able to make a thorough examination into the condition of the winding on the armature, both in the main winding and in the preventive-lead winding. These examinations have been very interesting. They indicate clearly that the armature windings are showing no dangerous overheating from the heavy loads that have been carried, and also that the preventive leads are showing no more evidence of heating than the main windings. If any comparison could be drawn, I would say that of the two, the preventive leads were in the better condition. Furthermore, only two instances have been found where there was a breakdown in the preventive lead. In other words, the record for these leads is better than that for the main coils themselves. But this is partly due to the fact that the preventive-lead winding lies underneath the armature winding proper, and is thus mechanically protected to a greater extent than the main coils. From the standpoint of experience then, these leads have proved to be one of the most durable parts of the equipment; taking everything into account, their record may be considered exceptional. If the rest of the New Haven system had shown anything like as good a record, there would have been no occasion for the greater part of Mr. Murray's paper. I think the time has now arrived when the "preventive" leads, as they should more correctly be called, should stand on their own merits, for no amount of criticism can belittle the record which they have made in the New Haven service.

Now consider the generators. No defect has developed in them which was not, to a certain extent, foreseen and apparently provided for, based on the data at hand. However, on the completed machine, the first and most pronounced source of trouble was heating, not in the winding, but in the field or rotor structure, due to the pulsating reaction of the armature winding when carrying a heavy load in single-phase current. This reaction was known previously to building these machines, but on machines of smaller capacity it had not developed destructive tendencies. It was proved later that this was simply because it had not been tried out under the conditions which would develop its most harmful effects. This pulsating armature reaction may be analyzed in the following manner:

Consider the armature winding as a magnetizing coil fixed in the space and carrying an alternating current. This coil may be considered as setting up an alternating field fixed in space. For analysis, this alternating-current field, fixed in space, may be considered as made up of two constant fields of half value, rotating in opposite directions at the synchronous speed of the machine. One of these fields therefore rotates at the same speed and in the same direction as the rotor. The other field is traveling round the rotor core in the direction opposite to its rotation. This field may therefore be considered as equivalent to one fixed in space with the rotor running in it at double speed. This armature, carrying single-phase current, could be replaced by an external direct-current field, and if the rotor were run at double speed in this field, an equivalent result, as regards heating, should be obtained. This core thus becomes an armature core subject to a heavy induction at a high frequency.

When the first rotor was built, the structure was laminated as completely as mechanical conditions would permit. However, in the case of high-speed turbine-generators of very large capacity, it is almost impossible completely to laminate everything, due to the fact that the mechanical requirements call for rigidity in some of the structural features. Upon testing the first machine it was found that there was local heating, with heavy load, sufficient to create hot spots in the core; and in a comparatively short time in turn these hot spots damaged the insulation on the coils from the outside, thus causing grounds on the winding. As soon as this was noticed, an effort was made to eliminate these hot spots; but it was found, after several attempts, that as soon as one was eliminated others would show up in some different place as soon as a higher load condition was reached. It was evident, after considerable work had been done, that the correct remedy was not being applied to this trouble. It was then decided to take a bold step by attempting to eliminate all pulsating reactions from the armature, by putting a short-circuited winding on the rotor, of such value that a very large current could flow in it with but very little loss. It was the idea to damp out the field in very much the same way that the armature of a polyphase alternator will demagnetize, or kill its magnetic field, if the armature terminals are all short-circuited together. It is known that under this condition the armature current will rise to such a value that the field flux is practically eliminated. In order to maintain this condition indefinitely without overheating, it is only necessary to put enough copper on the armature so that the I^2R losses in it under this condition are within the temperature capacity of the windings. Working on this theory, a complete cage winding was placed on one of the rotors of the New Haven generators. This rotor had not been designed originally for this purpose, and it was therefore difficult to adopt the most suitable proportions in this winding, but what was put on, immediately showed in practice that a practicable remedy had been applied for this trouble. Meanwhile the new rotors designed for the application of heavy cage windings were under construction, and upon the installation of these, the field or rotor trouble all disappeared. It is interesting to note that the fourth machine installed, which has a 4260-kilovolt-ampere single-phase rating, has a solid steel core, in the surface of which the copper cage winding is embedded. As this winding completely eliminated the pulsating armature reaction, there was no further occasion for laminating the field as a protection from magnetic pulsations.

I might add that a number of the earlier tests, leading up to the design of the first New Haven rotors, were misleading, in the fact that turbine-generators were used for obtaining the preliminary data for single-phase operation and, in all cases, the machines had solid steel cores. These cores acted as dampers to a certain extent, and this in itself eliminated part of the pulsation. It thus developed afterwards, that in the very act of lamination to avoid the trouble, we had gotten into it deeper.

Practically all this work on the generators was done before the full electric service was established, and while only one or two generators were required to be operated at one time. With one generator running, there was apparently but little or no disturbance due to short-circuits on the system. As the service was increased and two generators put in operation, the effect of short-circuits became more pronounced. When, in June 1908, the entire electric service was established, and three generators were connected to the system, it soon became evident that there was some serious condition existing in the system, as indicated by the extremely violent shocks to everything in case of a short-circuit. This was particularly noticeable in the switching system, and, as Mr. Murray intimates, in the case of a short-circuit, all the switches in the system felt it their duty to jump in and open the circuit. This indicated an abnormal current condition. It was calculated that these machines would give possibly six or seven times full-load current on the first rush, in the case of a dead short-circuit, this excess current dying down to possibly two or three times normal full-load current. All indications were, however, that this current was being greatly exceeded, and therefore a series of oscillograph tests were made to determine the current rush when the lines were purposely short-circuited under various conditions. These tests indicated that under certain conditions each machine could give, at the moment of short-circuit, almost 5000 amperes on one phase, the normal full-load current being 340. With three machines in parallel, this would therefore mean that approximately 15,000 amperes could be delivered momentarily. This enormous current rush was sufficient to explain many of the difficulties, but this was not all the explanation. The oscillograph tests also showed that this short-circuit current would be maintained at almost its maximum value for a very considerable period, due to the cage winding on the rotors of the generators. Apparently this current at the first rush, was not appreciably greater than that on the machine before the dampers were added, but without the dampers the field was killed more quickly by this enormous current, so quickly that apparently the breakers did not open until the current had fallen somewhat. However, with the heavy cage winding on the field structure, secondary currents were set up in this winding, tending to maintain the field strength, and thus the current rush was maintained at almost full value for possibly 20 to 30 alternations. These oscillograph tests indicated very clearly that the armatures of these generators did not have nearly so great internal self-induction as our calculations indicated.

Meanwhile, the generators in the power house had been suffering from the tremendous shocks which accompanied short-circuits on the line. There is necessarily considerable local field around the end-windings of all these machines, and this stray field is especially large on machines with a small number of poles, and, in consequence, high ampere-turns per pole. These stray fields at the ends tend to exert a bending or distorting effect on the end-windings. In any given machine the distorting force varies as the square of the current carried by the coils. Our experience with the windings on these machines indicated that they were being subjected to enormous forces in the end-windings. The oscillograph tests gave an indication as to the amount of this force. As the machines could give about 15 times full-load current momentarily on short-circuit, the force acting on these end windings would be 225 times normal; in this case, therefore, these forces were so great that it became a serious problem to devise a type of bracing on the end-windings sufficient to withstand such a force. It should also be borne in mind that probably as many short-circuits came, in one day, on these generators, as the ordinary high-voltage, power-house generator is called upon to sustain in one year. While ninety-nine shocks out of a hundred might not be sufficient to do damage, yet if the shocks occur frequently enough, the hundredth one will soon be reached. In our endeavors to support these windings against movement, probably the most complete system of bracing ever applied to alternating-current generators was developed and used on these machines.

But in spite of this there was evidence of movement at times. It thus became evident that some method of limiting this short-circuit current to the value originally intended; namely, about six times full-load current, would have to be applied. This was done by placing an unsaturated choke-coil, or impedance coil, on the trolley side of each machine. This coil takes up a comparatively small voltage under normal operation, but in case of a short-circuit, the electromotive force generated in it is sufficient to limit the current rush to less than half the value it would attain without this coil. Thus as the shock on the end windings of the generators varies as the square of the current, it is evident that cutting this current in half would cut the shock to one-quarter of its former value, which, with the method of bracing used on these machines, would mean the difference between good and bad.

When these choke-coils were installed, the results on the power house were evident. The shocks on the machines were very greatly reduced, so reduced that we do not fear future trouble from this source. It is interesting to note that No. 4 machine; that is, the 4260-kilovolt-ampere generator, referred to before, was put in service a considerable time before the choke-coils were installed, and it went through the most severe short-circuits ever encountered on this system. Its armature winding has never shown any distress. This is partly because, in the design of this machine, the difficulties to be overcome were known, and the remedies could be applied in the most suitable manner.

An interesting point in connection with the use of the cage windings on these generators, is that the apparent regulation of the system has been improved. This was anticipated, but the actual result in practice was more pronounced than was expected. In installing new rotors for these machines with the heavier cage dampers, the inherent regulation of the generators was made somewhat poorer than before, partly in order to accommodate certain structural features in the rotor. It was anticipated that the cage winding with its damping effect would, to a certain extent, mask this poor regulation by making the machine sluggish as regards fluctuation in voltage with sudden variations in load. In practice it was found that, with the later rotors with their poorer inherent regulation, the average regulation of the system was considerably better than before, thus indicating that most of the disturbances in the voltage, when the old rotors were used, were due to sudden changes in load, while the slow variations were taken care of by the automatic regulators. With the new rotors the voltage changes are so slow, that the Tirrill regulator has plenty of time to act before any serious disturbance can take place.

It must be borne in mind that in one way this New Haven power-house installation was more difficult than anything undertaken heretofore, and that is, in the use of 11,000-volt generators with one terminal connected directly to ground. Taking this condition into account, together with the enormous current rushes with consequent shocks on the winding, and the single-phase operation of units of such large capacity, it may reasonably be claimed that this was the most difficult case of alternating-current generation ever undertaken.

L. B. Stillwell: The writer of the paper is just emerging from a long and most trying contest with difficulties upon a conspicuous stage. The installation for which he is largely responsible did not attain, during several months of initial operation, that degree of reliability which the traveling public has a right to expect, and, naturally, it has been subjected to severe criticism. It is probably as a result of this criticism that Mr. Murray's paper is so constructed as to convey an exaggerated idea of the shortcomings of the system, while it fails perhaps to emphasize sufficiently the far-reaching importance of the fact that the single-phase alternating-current system is in actual service in the operation of this very important terminal and that this operation is successful. Its success is shown by a reduction in aggregate train delays when the present service is compared with the steam service which it has replaced.

Papers which set forth fully and frankly not only successful achievements but also mistakes, are of especial value, and all who appreciate the difficulties which beset the path of progress, and particularly members of this Institute who, by training and experience, are qualified to form well-grounded and just opinions, owe it to the officials and engineers, who have laid before us these valuable data, to regard and discuss the facts judicially and without prejudice, and to interpret them fairly to the railway world and the general public. I am sure we shall all endeavor to do this, but I trust that a cautionary suggestion will not be regarded as irrelevant, for the Institute is under exceptional obligations for this paper, not only to Mr. Murray but to the officers of the New Haven Railroad Company who have authorized its publication, for an opportunity to weigh and utilize operating data of a kind not often published.

The engineering world is fortunate in the fact that the New York Central Railroad and the New Haven Railroad have not adopted the same electric system. Such an opportunity to compare the possibilities and limitations of the direct-current system and the single-phase alternating-current system is unprecedented, and, except in America, would be impossible. Whatever we may think of the wisdom, from an economic standpoint, of investing millions to learn from experience, the answers to questions which by German methods, for example, might be answered at much less cost (and there is much to be said on both sides of this question) we as engineers are in no position to complain of lack of opportunity to subject our ideas to the test of practice. If, therefore, we fail to agree with reasonable promptness upon fundamental specifications of that system of electric equipment, which we shall advocate as a standard in railroad practice to be kept in view and ultimately used to the exclusion of the many possible but less desirable alternatives, we shall never see electricity applied in the operation of railroads to anything like the extent which its possibilities justify from an economic standpoint. Unquestionably, each and every problem of electrification should be studied primarily with reference to local conditions and requirements. In any given case it is conceivable that such local conditions and requirements may properly lead to the adoption of a system other than that which would be chosen to solve the more general problem of electrifying not only a terminal and limited suburban zone, but a railroad division or a trunk line. But we are all convinced that during the next ten years railway electrification will not be limited to terminals and suburban operation, within narrowly restricted zones. In this light the decision of the New Haven officials to adopt, in the equipment of its New York terminal, a system applicable not only to terminals but also to trunk line operation, and the frank presentation of results attained, should assist powerfully in the prompt evolution of that system which is fittest, and therefore destined to survive.

When Mr. F. J. Sprague, with clear conviction and admirable courage, installed the multiple-unit system of train operation on the Southside road in Chicago, a most important advance was made in the art of railroading. The applicability of this system to trains requiring tractive efforts exceeding 50,000 lb., was demonstrated first in the New York Subway. The equipment of the New York Central has contributed to our demonstrated utilities an excellent third-rail construction. Incidentally it has demonstrated most effectively, throughout the steam-railway world, the fact that under the conditions existing within the zone electrified, electricity can do the work of steam and do it better.

The New Haven installation, substituting 11,000 volts for 600 volts and eliminating sub-stations, opens the door to possibilities of electrification of railways, with its assured improvement of service and economy of operation, over zones far beyond the reach of the 600-volt direct current.

Under the conditions of respective development of the direct-current system and the single-phase alternating-current system, the decision of the New Haven management to use the system adopted was a bold one; and its boldness was emphasized by the selection of the highest standard voltage for which suitable alternators had been constructed.

With reference to the plan adopted to improve the overhead trolley construction which converts this to a catenary construction with secondary suspension cable, I observed in Hamburg recently that the single-phase system in use in that city employs this method of supporting the trolley wire.

In electric operation of railroads the three great links of the chain between coal pile and draw-bar, are the power house, the locomotive, and the system employed to transmit power from power house to locomotive. The power house and its equipment as constructed for alternating-current operation is practically identical with that constructed for direct-current operation. The only differences are that one phase is transmitted instead of three phases, and that one side of the circuit is grounded. The fact that the New Haven road has experienced an unusual number of delays, due to power-house trouble, is due to errors in the design of the generators and in the high-potential circuit-breakers. It seems that these errors could have been avoided by the exercise of that degree of care and foresight which an installation of such importance should receive. Of the ten electrical failures which occurred from July 1 to October 31, 1908, and involved delays exceeding 300 train-minutes in each case, eight were due, as Mr. Murray says, " to simultaneous failures of several circuit-breakers due to a short-circuit." This apparently might and should have been prevented by previous investigation of the ability of the circuit-breakers selected, to function under the conditions of service to which they were applied. Of the other two cases of serious failure, one apparently was due in part to a defective circuit-breaker; the other was a case of locomotive derailment.

So far as four months' operation may be taken as a guide, there is nothing in the record which is discouraging as regards performance of the electric equipment of the locomotives. If we except the delays due to circuit-breaker failures, the record is a good one.

It will add to the value of the paper if Mr. Murray will supply, for purposes of comparison, the record of train delays in steam operation during, say, the corresponding months of the preceding year. It is to be hoped also that the engineers of the New York Central will follow the example set by Mr. Murray and lay before the Institute a log of the New York Central electrification showing results attained as compared with preceding steam practice. This would afford an opportunity for accurate comparison of the results attained by the two contrasted electric systems in the operation of these important properties.

An incidental problem, which at one time appeared rather serious, but which apparently has been solved in an entirely satisfactory manner by the engineers responsible for the equipment of the New Haven Railroad, is the protection of existing telegraph and telephone systems from the effects of induction due to power currents.

Operation thus far has covered too short a period to justify final conclusions in respect of the reliability and safety of the high-potential overhead trolley and feeders, especially as the system has not been called upon to meet the conditions imposed by snow and sleet. If Mr. Murray will supplement his paper six months from now by a contribution giving the log of operation during the coming winter, and if some one representing the New York Central will favor the Institute with similar information, further conclusions of importance can be drawn.

E. B. Katte: If Mr. Murray could tell us in some detail of the troubles which led to the failures that caused the delays, it would help to a better understanding of the situation. He mentions two instances where no power was available on the direct-current third-rail. On July 8, the erecting men dropped a signal-mast across two tracks and broke down the third-rails, and there was a delay to trains while getting the third-rail up again. A few days later, on July 10, there was another delay of 13 minutes to the New Haven trains, due to no power on the third-rail. The third-rail was knocked down by a freight wreck, and there was some delay to traffic in clearing the tracks and in building up the rail. I think I can say that at no time has there ever been a lack of direct-current power available to apply to the third-rail when the third-rail was standing, and further, that when the third-rail has been knocked down due to a derailment or a wreck, it has been our usual experience that the third-rail has been re-erected and ready for service as soon as the wreck had been cleared and the track rails made ready for traffic.

H. P. Davis: In the operation of a railroad one condition stands ahead of all others; namely, the trains must be kept running and the schedule maintained at almost any cost. In this connection, Mr. Murray has presented, in a most striking way, a condition of vital difference between electric and steam operation of a railroad in the comparison which he has made of the delay chain. The importance of these conditions and the respective bearing of each of the links in this chain have received only slight attention in the literature of railroad electrification, but to those engaged in this work, it has been recognized as of vital importance, for the success of any large electrification is predicated wholly upon the infallibility of each link of this chain.

The usefulness of the electric locomotive is only realized with continuous and unfailing source of current supply. Realizing this, the working out of the problems presented in the power house, and particularly in the feeder and trolley system, are the most important presented to-day for our consideration.

As Mr. Murray points out, none of the separate links of this chain presents new principles, but when moulded together, some very astonishing characteristics have developed in the combination, when applied on a railroad system like the New Haven.

One of the preceding speakers has discussed most admirably the problems presented in the power house. It is my belief, however, that insurance in this respect really resolves itself into the question of sufficient reserve capacity. The really troublesome member of the chain is the link between the power house and the locomotive. The answer to the question: what is the best way to distribute current at high potential to a trolley wire over a busy railroad, with four or more parallel tracks, increased in places to several times this number, and connected at intervals to busy sidings and shifting yards is yet to be forthcoming.

For economy of conductors and high efficiency in transmission, the New Haven system will be hard to improve on. For in this system the 11,000-volt generators are connected directly to the line without the use of intermediate apparatus, thus eliminating all losses due to apparatus of this kind. The question whether it is the best for continuity of service and for operation with a minimum of train delays in case of trouble, time only will tell and is now, of course, open to argument and discussion.

The troubles encountered with the New Haven distributing and trolley system can be divided into two classes.

1. Those which have been constructional.
2. Those which have been a matter of operation.

Difficulties in the constructional features of the New Haven line have occurred, as pointed out by Mr. Murray. I look on this, however, as an unavoidable penalty, consequent to any pioneering installation, resulting from lack of knowledge and inability from previous experience correctly to forecast the conditions to be met.

It must be admitted that the problems encountered on this railroad are not simple, nor within the scope of ordinary or established practice. Many conditions have arisen impossible to foresee and guard against. It is only by encountering these difficulties that experience can be gained and data obtained to correct the constructional faults. Constructional difficulties, so long as they are not fundamental, do not affect the delay chain except to the degree of time sufficient to investigate the troubles and provide means to correct and eliminate them. The flexibility of the distributing and trolley system in operation is, however, of crucial and lasting importance in the delay chain.

Under the subject, "Distribution," Mr. Murray uses the word "disadvantages" in referring to this system. He should have used the word "difficulties." These have now been largely cleared up and have been shown to be only incident to a complete knowledge of what has been taking place in the system. In the last sentence of the paragraph above referred to, Mr. Murray says: "This operation can be effected, and at the time of this writing an effort is being made to obtain these results in practice." Since the preparation of his paper, most satisfactory results have been obtained with the scheme which has been developed, and as it introduces something new and likely to become general practice in power distribution, I shall briefly describe it.

Fig. 5, is a diagrammatic representation of the scheme of the New Haven trolley and feeder connections. By reference to this it can be seen that if selective operation of the circuit-breakers installed at each end of a trolley section can be obtained, in case of trouble in the section only the length of single track in that section will be affected. No delay to trains will occur, as they can be shunted on one of the adjacent tracks, except in case of not more than a single train, which might be in the section at the time of trouble. In principle this closely approximates the more advantageous feature possessed by the steam unit in confining delays to individual trains in case of trouble. Attention is particularly called to this to show that careful thought was given to this feature of the problem in planning the installation, and that its importance was recognized.

In practice, the failure of the line to operate as laid out was for a considerable time extremely puzzling. The destructive action of short-circuits on the circuit-breaking apparatus, on the generator windings, on the insulation of the line, and the failure of the circuit-breakers to be selective, could not be explained by any previous experience. A careful and thorough study of the nature of these disturbances by means of the oscillograph showed current surges of great severity, both as regards amount of current supply and the duration of the surge. It was shown, for instance, that with three generators connected to the line, it was possible for them to deliver at times as much as 120,000 to 150,000 kilovolt-amperes single-phase, and to maintain it for a period approximating one second.

It is not surprising, that circuit-breaking apparatus set for instantaneous operation failed, and that it was not selective in action, for the automatic trips on the trolley breakers were set to act at currents so low as to be out of all comparison with the amount supplied, and as the feeder and trolley arrangement is a series-parallel one, there was more than enough current in the distributing system to trip them all over the line. It was apparent, as soon as it was realized what the trouble was, that:

1. The generators must be provided with some sort of a shock absorber to protect against the first rush of current at times of short-circuit.
2. The opening of the circuit during times of heavy current surges must be prevented, because of the possibility of violent voltage surges from such operation with resulting destructive effect on the insulation of the system.
3. The current supply in the distributing system on short-circuit must be controlled, and automatic operation of circuit-breaking apparatus must be prevented until this condition was established.
4. The line sections must be made selective.
5. Corrective apparatus should be simple and automatic.

To meet the first condition, choke-coils were placed in the trolley phase of each generator, the coil being permanently in circuit. This coil is designed to cut down the maximum short-circuit current values to about 40 per cent, and the resulting mechanical shock to about 16 per cent.

To limit the current to be opened in the distribution system, and to make the selective action possible, was a more complicated problem and has been solved in the following manner.

Ohmic resistances have been placed in each of the three feeder leads going to the distributing system. These resistances are normally short-circuited by circuit-breakers. These circuit-breakers are electrically operated, and are automatic in opening and closing, being controlled by a single underload and overload master relay, so installed that the entire station single-phase output passes through it. The automatic tripping coils of the circuit-breakers on the overhead feeder and trolley systems are normally cut out; in other words, these circuit-breakers are normally non-automatic; the automatic operation being controlled from the power house.

In the event of a short-circuit or overload on the system exceeding a certain predetermined current, the master relay above referred to operates, causing the circuit-breakers short-circuiting the resistances to open. The resistance is thus automatically inserted in the feeder circuits. The value of this resistance is sufficient to reduce the current to a certain fixed and predetermined value. As soon as the resistances have been inserted in the feeder circuits, a feeder wire connected with all of the trolley and feeder circuit-breakers is then automatically supplied with potential. This at once makes the circuit-breakers automatic throughout the feeder and trolley system.

Each of the trolley sections terminates at anchor bridges. These bridges serve the double purpose of anchorages for the trolley structure and of sub-stations for current distribution to the adjacent trolley sections. Current is fed from the power house to the bus-bars on these bridges by feeders supplemented by the entire trolley system. The whole distributing system is, therefore, multiplied at each anchor bridge. Each end of a trolley section connects to the bridge bus-bar through a single circuit-breaker. In case of a short-circuit in a section, it is evident that these two circuit-breakers will have the total current flowing, divided between them. As the remainder of the system is in multiple with the bridge bus-bars, these two circuit-breakers will be carrying much more current than any others.

With this circuit condition established, it is only necessary that the power-house resistance shall be so proportioned that it will allow sufficient current to flow, to trip the two circuit-breakers in the trouble section, and yet limit the amount of current to less than enough to trip any of those in parallel in the remainder of the system.

With the current reduced to this definite amount, it divides through the system properly, concentrating at the point of trouble. The amount of current is, as pointed out, less than the amount required to operate any of the circuit-breakers, except those adjacent to the point of trouble. As soon as these two breakers open, the troublesome section is disconnected, and the current in the power house will at once drop to normal value. When this happens, the master relay at the power house will act again, and cause the circuit-breakers shunting the resistance to close and short-circuit it. At the same time, the feeder wire connecting to the automatic trips on the circuit-breakers of the trolley system will be opened, thus leaving the whole outside system again non-automatic. This entire cycle is accomplished automatically (without the use of delicate or complicated apparatus), power never being removed from the line. The whole cycle takes only about two seconds.

If it happens that one or both of the circuit-breakers at the ends of a trolley section fail for any reason to operate, and thus do not clear the line, it is arranged that the main circuit-breakers at the power house will operate and open the entire circuit. To accomplish this, the main power-house circuit-breakers are provided with time relays of the constant time type, set so that they will not act until a sufficient period has elapsed for the trolley and feeder current breakers to open. This condition is, however, of rare occurrence.

The use of a scheme of this kind, in which ohmic resistance is thrown in series with the distributing system at the first rush of current to a short-circuit, has other advantages beside that of making the system selective; for it effectually prevents much line disturbance directly traceable to violent opening of heavy currents by circuit-breakers, and to making circuit again under these conditions. As the trolley and feeder circuit-breakers are normally disconnected, the circuit cannot be opened at the first rush of current. The resistance being inserted in circuit first, the current is lowered to a value which is sufficient to trip only the circuit-breakers on each end of the trouble section.

When the circuit-breaker does act, it is called to open a practically non-inductive circuit, so that voltage surges cannot be produced, thus safeguarding the insulation of the system. For the same reason when power is thrown on the line the resistances act to damp out any surging effect. This arrangement provides a method of limiting line disturbances; for no matter how severe the short-circuit, or how great the amount of power available in the generating station, the circuit-breaking apparatus cannot act under conditions which will destroy them or cause destructive effects in any part of the system. It also has the advantages of being entirely automatic in action and effectually overcomes, without service interruption, effect of flashes, which are common in a system like the New Haven. In a case of this kind, when no permanent ground exists, the automatic insertion of the resistance into the line will usually cause the flash to be extinguished without interruption of service and without harmful effect. This method is simple, automatic in action, and most effective in controlling and regulating destructive line effects, and will, I think, either in this form or in some modification, be used quite generally in future in distributing systems of this kind.

Philip Torchio: In the paper, the main cause of the considerable troubles due to circuit-breakers is ascribed to the fact that the type of breaker used had the oil-tank grounded. The author suggests that the lining of these tanks should be improved. I would ask why, in the corrective changes introduced to overcome this deficiency of the circuit-breakers, no consideration was given to the obvious types of circuit-breakers which have the oil-tank insulated from ground. I would also like to ask why, in a single-phase electrification, three-phase generators were used in preference to single-phase generators? Would it not have been preferable to adopt single-phase generators? By using single-phase the company would eliminate, of the numerous generator troubles, those troubles which seem to have caused repeated rebuilding of the field of the generators on account of local heating resulting from the magnetic distortion due to the single-phase load upon three-phase generators. This magnetic distortion would have been considerably less with a single-phase generator.

C. P. Steinmetz: The importance of to-night's paper and discussion consists in the explicit and concise information which it gives as to the progress in the development of the electrification of a part of one of the country's trunk lines by means of the single-phase alternating-current motor. It is especially gratifying to see that the statements which have been made by unbiased engineers based upon theoretical considerations, have now been verified by practical experience, and that heavy railroad work can be handled by single-phase, alternating-current motors, though obviously not with the same high drawbar pull per ton of locomotive weight, and, possibly, at least for the present, not with quite the same reliability of service.

This I believe establishes the single-phase alternating-current motor as one of the pieces of apparatus by which the future electrification of our country's railway systems will be accomplished. The drawbar pull per pound of motor weight of the single-phase, alternating-current motor must necessarily be lower than that of the direct-current motor, because in the alternating-current motor the magnetic field pulsates between zero and a maximum. The same motor, when energized by direct current, with the same maximum magnetic flux, would give 41 per cent more output. It is important, therefore, to know that in those cases where direct-current motors cannot be used; for instance, where heavy train units at infrequent intervals traverse long distances, the work can be done by alternating-current motors. I believe when the time arrives to electrify our transcontinental railways, this will be done by means of the alternating-current motor.

My conclusions from the evidence and data now available are the same as I have expressed before; that those railway problems which cannot be handled by direct-current methods must be solved by means of the alternating-current motor. But where direct current can be used equally as well as alternating current, the higher weight efficiency; that is, the greater drawbar pull per pound of motor weight afforded by the direct-current motor, necessarily makes this motor preferable from the electrical engineer's point of view.

It is interesting, then, to observe that in those immediate railway problems which can be handled by alternating-current motors as well as by direct-current motors, the decision whether one or the other type of motor should be used has shifted from the electrical engineer to the railway engineer or the railway manager. This decision will be determined by the economic question whether higher weight efficiency; that is, higher draw-bar pull per pound of motor weight and reliability of service, should be sacrificed because of the possibility, at some future time, when the electrification of railroads for long distances is proposed, of being able to extend the same system of operation over remote parts of the road, and also to other roads where direct current can not be used; or whether the higher weight efficiency of the direct-current motor, and the at present greater reliability of service, compensates for the possibility that at some future time with the advance of the electrical industry and the extension of railroad electrification, we may have to replace the locomotive equipment, or change locomotives at the end of the direct-current zone and the beginning of the alternating-current zone.

Minor M. Davis (by letter): It is possible that Mr. Murray's remarks about the effect of single-phase currents upon telegraph and telephone wires will be misunderstood. Transformers are by no means completely corrective, although to some extent they are beneficial. My understanding is that the transformers on the New Haven road are applied only to single-wire operation and that they do not neutralize the disturbing effects of the single-phase electric current sufficiently to permit the operation of duplexes, quadruplexes, and printer circuits upon the wires to which Mr. Murray refers. This means that one-half or two-thirds, or even a larger proportion, of the carrying capacity of the telegraph wires is destroyed, notwithstanding these transformers. To apply these transformers, several otherwise idle wires must be carried upon the poles, and these wires and transformers are objectionable. They complicate single-wire equipment and prevent the operation of multiplex systems. Although Mr. Murray refers to the pilot wires and transformers as "not costly", they mean considerable expense. It is more or less of an open question, as I understand it, whether it is the duty of a corporation to prevent its electric current interfering with the current of another company, or whether it is the duty of the latter to provide its own protection. I understand the highest court in New York state has ruled in one of its decisions that if a party:

> Collects for pleasure or profit the subtle and imperceptible electric fluid, there would seem to be no great hardship in imposing upon it, or him, the same duty which is exacted of the owner of the accumulated water power: that of providing an artificial conduit for the artificial product, if necessary to prevent injury to others.

Certainly there is no disposition on the part of the telegraph companies to retard in any way the advancement of the art of applying power. They are willing to exercise all reasonable patience, and they would be glad to have the power companies adopt a simple and inexpensive remedy for these disturbances; but although the writer and his associates have given much attention to the subject they know of no remedy which is at the same time simple, inexpensive, and complete.

B. A. Behrend: The single-phase generators have been a source of great trouble, the cause of which was not immediately recognized. The heating of the units due to the variation in the armature reaction was overcome by low-resistance circuits placed in the rotor surface, and acting as the secondary winding of a transformer. This winding, however, reduced the effective reactance on sudden short-circuits, resulting in great increase of the momentary short-circuit currents, and in disturbing forces corresponding to the square of these currents on the armature conductors. Both these difficulties were minimized by reactance coils placed in the feeders. I should like to ask Mr. Murray what reasons have prevented the adoption of two-phase generators in the New Haven case, and what are, in his opinion, the objections in general to two-phase generators for this class of service.

The difficulties experienced with the collection of current are not specifically connected with the single-phase system, but they are, at present, an essential part of all systems of electric railroads employing high potential. An inspection of the line and the flashes produced by imperfect contact, which I had an opportunity of making since the steel wire has been installed, indicated that great improvements have been made in that direction.

The difficulties experienced with the single-phase locomotives and the motors in particular, are the vital issue. Through the courtesy of the New Haven road I had the opportunity of observing the motors of a heavy two-engine train between the Grand Central station and Stamford, Conn. The operation on both direct-current and alternating-current power is very much alike, as far as sparking is concerned. In fact, the eight motors operated very well and without undue sparking, both in starting, and at about 65 miles an hour. No unbiased observer of experience with electric-traction apparatus, can close his eyes to the fact that, if such results can be obtained in the first large plant of this nature, very much better results may be predicted for the system in the future.

The temperature rise on alternating current is naturally greater than on direct current. It would be extremely interesting to obtain comparative figures from Mr. Murray on this subject. This matter is intimately tied up with the question of efficiency to which Mr. Murray has alluded, without, however, going into figures.

H. F. Parshall (by letter): In 1901 I was appointed by the Board of Trade a member of a tribunal, presided over by the Hon. Alfred Lyttleton, to determine whether or not such an alternating-current system as proposed by Ganz was suitable for the underground railways of London. The matter was most thoroughly investigated from every point of view. I came to the conclusion, which conclusion was supported by the umpire, that the alternating-current traction system was not the best for working a heavy passenger service. My reasons were that the alternating-current motor is at serious disadvantage as compared with the direct-current motor during the period of acceleration; that from the nature of things it is inherently heavier and more complicated, and must be more expensive as regards first cost, and vastly more costly to maintain; that the sole advantage incident to the use of an alternating-current motor is in the supposed saving in the first cost of the collector system; that when a high-tension system is safely installed it must be more expensive than a third-rail system—consequently the whole reason for the existence of an alternating current system disappears in the final result. Since 1901, material progress has been made in the design of alternating-current motors, and the greatest credit is due to those engineers who have brought the alternating-current motor to its present high state of perfection. Nothing, however, has occurred that would justify me in departing from my original conclusion. In the beginning it was suggested that the alternating-current motor would not have a commutator, and that this evil inherent to a direct-current motor would be dispensed with. In the final result, however, a commutator 50 per cent bigger than the direct-current commutator has been found necessary. The perfected alternating-current motor weighs about 40 per cent more, has all the objectionable features of the direct-current motor and practically twice over, on account of the construction of the stator. The air-gap of this motor in practice may not exceed 60 per cent of that of an efficient and well-designed direct-current motor. Higher armature speeds have generally been found necessary. With the features above mentioned inherent to alternating-current motors, the first cost of a train equipment, as also the maintenance, must be nearly double that of a direct-current equipment of like capacity. Further, I doubt in the heaviest class of electric traction installation, such, for instance, as that in the New York Subway, whether the alternating-current motor can be made to do the work satisfactorily at all, over a period of time. In addition to the above well-known features of the alternating-current motor the use of a train transformer has to be considered. What ultimate size and form this transformer may take in heavy, high-speed work remains to be determined, since with a jumping contact the strains on this transformer are practically incalculable.

I think it must be conceded by all, that the alternating-current train equipment, *per se*, is inferior as regards cost and maintenance to a direct-current train equipment, and that it gives no tractive advantage. The advantage, then, must be external to the train, and confined to the system of transmission, or more properly the collector system, since the transmission system would naturally be the same either with direct current or alternating current. As a matter of experience it has been found that the cost of a high-tension overhead system properly installed is greatly in excess of that of a third-rail system, and having regard to the exceedingly numerous difficulties, as put in evidence by Mr. Murray's paper, it cannot be contended that the action of an overhead high-tension system is anything like as satisfactory as the third-rail system. Considering all that has gone on in the New Haven system up to September 5, 1908, which appears to be the termination of Mr. Murray's log, there is absolutely nothing to indicate that during 1909 some such series of occurrences are not again to be expected. All that has occurred may be expected to occur again in some form or another, since electric traction apparatus does not manifest all its faults during the first few months of operation.

The absolute lack of commercial data as regards the cost of the installation, cost of operation, and cost of maintenance vitiates any conclusion that may be drawn other than that the system when compared with such a system as has been installed by the New York Central is entirely unjustified by the practical results. Some two years ago I was shown a diagram of the feeders and electrical system of the New Haven Railroad. I could only state that it transgressed every established principle as to safe and reliable working, and that if the system as a whole were to be in any way justified, there was no excuse for starving the system of feeders to such an extent, and mixing up what might be properly termed the collector system with the transmission system. In my judgment many of the troubles that have been experienced would have been avoided had the alternating-current system been installed in accordance with accepted alternating-current practice, with a high-tension system of transmission, say from 20,000 to 30,000 volts with substations at the different sections and a trolley voltage not exceeding 5,000. The cost need not have been greater, and the system would have been far and away safer, in that the different sections could be independently controlled. Further, the volume of stray current in the earth causing electrolysis and induction troubles would be greatly lessened. The system has apparently been designed on the assumption of the undisputed right to the wholesale use of the earth as the return circuit.

As regards the difficulty experienced with the generators, the New Haven line is not unique in this respect. With a feeder system, however, designed as above, it is doubtful whether the generator windings would have been displaced, although the use of a train transformer and a jumping trolley contact may be expected to introduce unexpected phenomena. Looking at the alternating-current system broadly, it seems to me that its advocates are more interested in the electrical than the mechanical aspects of the electric traction field, and its opponents are those who have had the longest experience in traction matters and are not inclined to experiment with the fundamental elements of a traction system, considering the sole and total advantage that can seriously be suggested is cheapness. Why a railway should spend its tens of thousands per mile endeavoring to make a system as safe as possible, and then attempt to effect a minor saving by the introduction of a system bringing with it fatal and most experimental elements, is beyond my comprehension. Mr. Murray states that there have been no fatalities so far as the public is concerned, nor would one expect such fatalities considering the short time the system has been in operation and the overhauling to which it has been subjected. In the fulness of time, however, there may be collisions, derailments, or some such occurrence, in which the overhead system will be disarranged, at the same time as passengers debouch from the trains. The result of an occurrence of this description will in my judgment sound the death-knell of the alternating-current system so far as a passenger service is concerned. It is stated that there have been several fatal accidents to the employees. The number is not given although I have been informed it is considerable, and in the nature of things it must be so. Men are required to maintain a good train service, and throughout the world it is recognized, sacrifice their safety to the public needs. When, however, an element of certain death so insidious as a system of high-tension conductors is made an accessible and working part of a railway system, nothing but a long list of fatalities can be expected. No amount of rules and regulations will ever suffice to make a system, having inherent fatal elements, safe to the employees, in fact, having regard to the exigencies occurring in normal railway practice, rules and regulations in general may be taken as existing in form and not in substance.

I regret to have to make use of Mr. Murray's expression in stating as my conclusion that his paper furnishes conclusive material of how not to install a traction equipment, and it appears to me the only way he could possibly justify his belief as regards the commercial usefulness of the system would be by the publication of such commercial data as would show that the alternating-current system as regards first cost and cost of operation has such material advantages over the direct-current system that all such occurrences as are recited in this paper are as nothing considering the proved commercial advantages.

To summarize, I may say I am responsible for the electric traction installation of the Central London Railway. While this was one of the first systems to employ multiphase transmission with synchronous converters and a direct-current collector system, none of the troubles instanced by Mr. Murray has been experienced, and since the installation opened there has never been, all told, an hour's delay caused by any electrical failure; in fact the whole service has been characterized by the utmost regularity and freedom from trouble either electrical or mechanical. Since the installation was designed, considerable improvement has been made in motors, so that with the interpole construction higher voltages are practical. Also with the under-running protected third-rail system these higher voltages can be safely employed without risk either to the public or to the staff of the company. Having regard to the history as regards reliability and freedom from trouble with a third-rail system, as also the wider field over which it is applicable on account of the above improvements, I am of the opinion, so far as the working of passenger services over the widest districts is concerned, that the direct-current system of electric traction is superior to the alternating-current system for dense traffic movements, and in the majority of cases in which electricity can properly compete with steam. That there are problems in connection with freight haulage over long distances in which the multiphase system possesses commercial advantages, I do not feel in a position to deny, although an examination of the individual cases which have been submitted to me has not in my judgment made this an indisputable fact. As regards the single-phase, alternating-current system there may be special applications to which it is commercially applicable. I have given the deepest study and thought to various problems, but in each case the use of the single-phase system has proved illusory. I do not wish to go further than to state that I have not found a problem to which it is properly applicable, considering all the facts as I now see them. I have recently pretty thoroughly investigated railway matters in the United States and, considering the inherent properties of the different classes of apparatus, my conclusion is that the direct-current system of electric traction is superior to all others, and is likely to remain so for many years to come.

A. H. Armstrong: The enthusiastic coöperation of the engineers of the railroad company and the manufacturing company has brought this alternating-current installation to its present engineering success, and nothing but admiration can be expressed for the courage and ingenuity shown in overcoming the difficulties met with in operation.

It is my understanding that the alternating-current single-phase system was adopted in the New Haven installation in order to afford an opportunity to demonstrate the suitability of that system to the possible further electrification of the road. It is further my understanding that preference was given the system chosen, for the reason that it was considered to be a cheaper system as to first cost than either the 600 or the 1200 volt direct-current systems, proposals upon which were also received.

As pointed out in the paper, the overcoming of difficulty after difficulty met with in operation, is positive proof of the progress made in perfecting the complete electrical and mechanical equipment. Material changes have been made both in the construction of the locomotives as well as in the generating and distributing system, so that the final installation as now in operation is widely different from the original plans, both as to engineering details as well as to first cost of the apparatus finally installed. Certain changes were made in the generators, in the switchboard controlling apparatus, etc., in order to obtain increased capacity and reliability, these changes presumably resulting in a somewhat increased cost over that of the original plans.

The trolley construction as now installed embodies certain improvements, as pointed out in the paper. A considerable departure must have been made from the original plans in order to account for the large difference in the estimated cost of this part of the installation, before and after its completion. In the December issue of the *Street Railway Journal*, 1905, Mr. Westinghouse publishes his estimate of $12,436 per mile as sufficient to cover the cost of contact line on a four-track road between Woodlawn and Stamford. Presumably this figure covers the same labor and material, estimated to have actually cost nearly $55,000 by Mr. Wilgus in his paper before the American Society of Civil Engineers. In view of the wide discrepancy between the cost of the trolley construction as proposed, and as completed, it would be instructive to know which of the two figures is nearer the actual construction costs.

The locomotive changes found necessary are most frankly stated by Mr. Murray. They have been extensive, and those listed are presumably the changes after the original locomotives were received, and developed defects in practical operation. The author also states that the locomotives have fulfilled their guarantees as to their capacity to haul 200 tons trailing. A log of the run giving the time required to haul 200 tons trailing with 45-second stops averaging 0.451 per mile would have been most interesting. If the present locomotives fulfil the guarantees as to performance of a 26 miles per hr. schedule with a 15 per cent margin in time, it may account for the increase in locomotive weight from 68 tons total, as proposed, to 102 tons as now in operation.

It is reasonable to suppose that the cost of these locomotive units has increased in at least a like ratio, although it is my experience that it costs considerably more to construct an alternating-current single-phase locomotive than one of equal weight equipped with direct-current motors. We are therefore impressed with the fact that in this completed New Haven alternating-current installation many changes have been found necessary, not only in the apparatus as originally furnished, but also in the original plans upon which the decision to adopt alternating-current motors was presumably based.

Published figures of trolley construction indicate that this item was estimated at but one-fourth the actual cost, while the increase in locomotive weight would account for at least an increase of 50 per cent in the cost presumably used in the original estimates. The large increase in cost of these two items may be accounted for, either by an error in the original estimates, or by the assumption that continued development of the alternating-current single-phase system has called for more liberal construction, greater factors of safety, and a readjustment of ideas previously formed.

While preference may originally have been given the alternating-current motor for this installation, with the limited knowledge of its operation then considered, I find it hard to justify Mr. Murray's present enthusiasm for a system that appears to be in many ways unsuited to the New Haven conditions. In this connection, I will state that the weight of the locomotives as now installed approaches fairly close to the weight of the locomotive which I estimated was required to perform the service originally specified.

No operating company can afford to submit to the traffic interruptions and delays outlined in Mr. Murray's paper, unless the object to be attained be of the most far-reaching character. In view of the fact that the alternating-current trolley construction as installed on the New Haven apparently costs 80 per cent more than a 600-volt third rail, and the alternating-current locomotives cost at least double for the same service performed, it is instructive to compare the operating results secured with the two systems.

COMPARATIVE DATA ALTERNATING-CURRENT AND DIRECT-CURRENT LOCOMOTIVES

	600 volt d.c.	New Haven 11,000 volt a.c. 600 volt d.c.
Weight total	94.5 tons	102 tons
Weight on driver	68.5 "	77 "
Number of motors	4	4
Total h.p., 1 hr. rating	2200	1000
Guaranteed trailing load	400 tons	200 tons

The locomotive weights given above, include pony trucks on both locomotives.

Having approximately the same total weight, a single New York Central locomotive unit has a capacity equal to two New Haven units, although the motors of the latter are cooled by forced ventilation, while in the New York Central motors natural ventilation is employed.

Much has been said to-night about the New Haven locomotives meeting their guarantees, and handling a trailing load of 200 tons, and also the wisdom of not adopting a unit of any larger capacity on account of the average weight of trains on the New Haven road being approximately 212 tons. I have drawn up a list of the trains drawn on November 21 by the New York Central locomotive unit, a single unit. This list comprises a majority of the trains handled that day which exceeded the guaranteed trailing load of 400 tons.

NEW YORK CENTRAL LOCOMOTIVE PERFORMANCE

Trailing Loads in Excess of 400 tons, Nov. 21, 1908

Train No.	Weight	Train No.	Weight
Special	475 tons	7	480 tons
"	570 "	71	471 "
54	416 "	Special	571 "
14	430 "	"	424 "
18	424 "	"	558 "
28	434 "	"	483 "
26	491 "	"	420 "
16	468 "	"	475 "
10	445 "	"	506 "
58	628 "	"	482 "
22	411 "	"	460 "
23	467 "	"	550 "
27	441 "	"	572 "
31	524 "	"	536 "
17	439 "	"	558 "
33	475 "	"	570 "
9	454 "	"	575 "
19	668 "	"	571 "
3	515 "	"	650 "
41	465 "	"	519 "
29	541 "	"	600 "
59	516 "	"	560 "
37	420 "	"	569 "

It is to be noted that every one of the above trains hauled by a single direct-current New York Central unit would have required two New Haven alternating-current units.

The reliability of the direct-current and alternating-current system is clearly illustrated in the following table of train-minutes delay for the months of July to October 1908, inclusive. The alternating-current figures are taken from Mr. Murray's paper and the direct-current figures from the New York Central operation. The figures for the New York Central operation are not official, but doubtless Mr. Murray can correct any error with his possible access to official records.

TRAIN-MINUTE DELAYS, CENTRAL AND NEW HAVEN, 4 MONTHS, JULY-OCTOBER, 1908

	New York Central	New Haven
July	41	2281
August	53	1611
September	18	893
October	48	910
Total	160 min.	5695 min.

The New Haven figures make no note of delays of over 300 minutes. The Central figures include delays due to locomotives or operators only, as during these four months there were no delays due to generating, transmission, sub-stations or third rail and feeder distribution systems, in spite of the alleged complication of such a system.

It is difficult to assign any exact field for alternating-current motors, but it is my conviction that under the conditions outlined in Mr. Murray's paper, the installation of the alternating-current system is a mistake, and that Mr. Murray has not shown any reason for his statement that if three years ago he was in favor of the alternating-current system for the conditions outlined, he is much more in favor of it to-day. In view of the fact that the generating station does not cost less, that the overhead trolley construction costs 50 per cent more than a third-rail construction, that the locomotives cost fully double that of corresponding direct-current locomotives of the same capacity, it is hard to find any justification for the enthusiasm displayed for the alternating-current system installed under the conditions outlined in the paper.

N. W. Storer: In his remarks, Mr. Armstrong makes comparisons between the New York Central and New Haven locomotives. A table is given in which the weight of the New York Central locomotive is stated to be 94.5 tons, while that of the New Haven locomotive is given as 102 tons. Following this table is the statement that the locomotive weights given include pony trucks on both locomotives. As to the exact weight of the present New York Central locomotive, I am unable to give any information, except that it has usually been given as about 97 tons, instead of 94.5. However, it is well known, and has been announced in the technical press that all the New York Central locomotives are to be reconstructed by changing the two-wheel trucks to four-wheel trucks, and that the weight of the modified locomotive is between 115 and 120 tons. Of course, as the New Haven locomotives have been modified so much faster than those on the New York Central, their weight may be temporarily slightly in excess of the New York Central locomotives, but, to be strictly fair in the comparisons, Mr. Armstrong should have given the final weight of the locomotives.

Mr. Armstrong also states in his table that the guaranteed trailing load of the New York Central locomotive is 400 tons, and that of the New Haven is 200 tons. The trailing loads of these two locomotives should, of course, be compared in the same kind of service. The New York Central guarantee was based on express service with long layovers. The New Haven locomotive was guaranteed to handle a 200-ton trailing load in *continuous local service*. These locomotives are guaranteed to handle 250 tons in local service as far out as Port Chester, a distance of 25.6 miles from Grand Central station. They also handle 300 tons trailing load in local service to New Rochelle, a distance of 16.6 miles. In express service, which is the class of service on which the New York Central guarantee was based, the New Haven locomotive handles easily a load of 300 tons.

In Mr. Armstrong's table, therefore, there should be substituted a weight of not less than 115 tons as the weight of the New York Central locomotive, and 300 tons as the guaranteed trailing load of the New Haven locomotive.

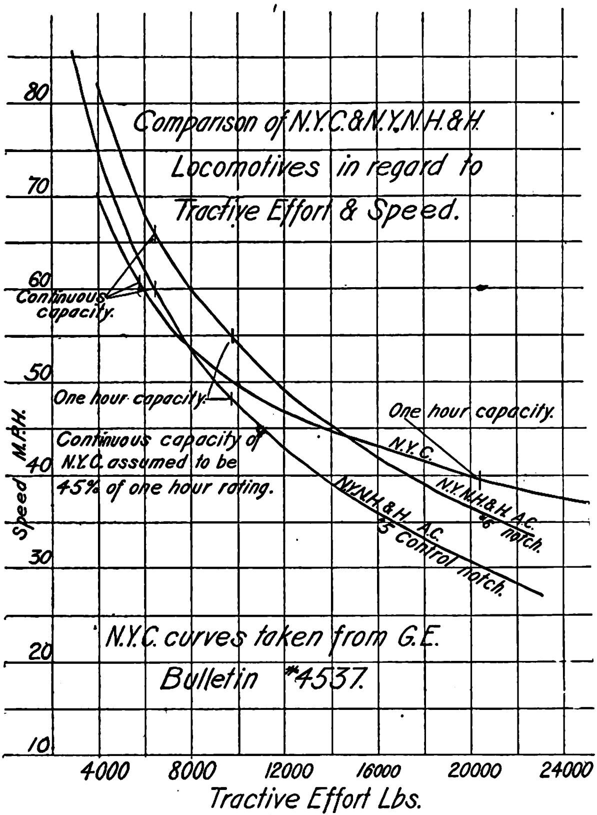

Fig. 1.

No one is more anxious than I to give the New York Central locomotive full credit. I believe that it is doing most excellent service. But what is the service. Simply switching—nothing more or less. There are a few trains that have to be hauled out to Wakefield, a distance of about 12 or 13 miles. The remainder of the trains are changed at High Bridge, which gives a distance of only about 6 miles for the locomotives to handle the majority of the trains. This is anything but trunk-line service. The distance is so short, and the service necessarily so intermittent, that the locomotives should be able to work at a load far in excess of the one-hour rating without overheating. They are, therefore, able to handle the heavy trains without double-heading, as was intended where the electric zone was laid out. It is a noteworthy fact that since the wreck of the Brewster express, these locomotives have never been run double-headed. It is also noteworthy that after that date the limiting speed on the New York Central electric zone was 45 miles per hr. until recently, when it has been raised to 50 miles per hr. Under these circumstances, it is impossible to make comparisons between them and the New Haven locomotives, which are and have been operating in all classes of service, running most of the time at very high speeds. If the New York Central locomotives should be reconstructed so as to make them safe for high-speed express service, and the company carries the electrification to the limits originally considered, there may be a chance to compare the two locomotives on a fair basis. At present to talk about the enormous trailing loads handled by the New York Central locomotives is misleading.

Mr. Armstrong mentions the great increase in weight of the New Haven locomotive over what he thinks was the original estimate. He is in error in regard to this point. The original estimate for this locomotive was 78 tons. The first one built weighed 89 tons. The electrical equipment installed in the first locomotive weighed 10 or 15 per cent more than the estimate, and has been increased very little since then. The additional weight which has been put into these locomotives has been almost entirely in mechanical parts, steam heaters, etc. One thing must be borne in mind: the electric locomotive of the future will be designed so as to have good riding qualities, and to secure them, the mechanical parts will form a much larger part of the total weight than was thought necessary or desirable two or three years ago. This feature in itself will bring the weights of the single-phase and direct-current locomotives much nearer together.

When discussing the question of cost, why is it that the increase in cost of the New Haven installation over and above the supposed estimates is so much under discussion, while in the New York Central installation nothing is considered except the cost of locomotives, and possibly that of a straight section of third-rail. I should be more than glad to see the total official cost of the New York Central installation side by side with that of the New Haven. Without such figures, it is useless to discuss costs. However, it may be noted in passing that the statement of Mr. Wilgus in a paper read before the American Society of Civil Engineers, that the cost of electric current must be increased from 0.58c. per kilowatt-hour at the power house to 2.6c. at the shoes of the locomotive to cover the cost of operation, investment, etc., foreshadows some enormous expenses.

Concerning double-heading. Much has been said about the number of extra locomotives required for the New Haven Railroad, on account of being obliged to operate 25 per cent of their trains with two locomotives. In this connection, a query arises in my mind. Why is it that the New York Central finds it necessary to buy 12 additional locomotives, making 47 in all, while the New Haven Railroad can get along with 41 locomotives of such an extremely small capacity as they are supposed to have, in handling all of their traffic as far as Stamford, it being borne in mind, of course, that the New York Central operates a large number of multiple-unit trains. Let us have some actual figures in regard to the New York Central installation, both in regard to cost of installation, cost of operation of power stations, sub-stations, distributing system, etc., and in regard to the mileages, etc., of their locomotives.

O. S. Lyford, Jr. (by letter): In developing its plans for electrification, the Erie Railroad Company has adopted the method advocated by one of the speakers. It commenced its work on a moderate scale on a branch line with 34 miles of track and 6 motor cars. This may seem at first to be insignificant compared with the New Haven system; but the mileage is 30 per cent of that of the New Haven, the number of motive power units 15 per cent, and the capacity of each motive power unit 40 per cent. The line is operated with 11,000-volt, single-phase trolley. It was constructed during the operation of the road by steam locomotives, and the division is now being operated by both steam and electric motive power. This line has been in operation 18 months with the following results:

Safety. One man lost his life during the first few days of operation by coming in contact with the trolley wire. This was an employee who had been carefully instructed but "forgot." There have been no other personal injuries to employees or to the public due to the electrical equipment.

Reliability. In October 1908 there were no detentions chargeable to the electrical equipment. In November there were four detentions of this character; one due to control trouble, two due to hot motor bearings, one due to breakage of air-compressor crank shaft. Three of these detentions were of a character preventable by more rigid inspection.

In December there had been no detentions up to the date of the meeting.

It should be noted that only one detention was due to a strictly electrical cause, and none was due to high voltage or to the single-phase features of the equipment.

It is believed that this record of nearly 2.5 months will compare favorably with any other electrically operated road. This record, however, was obtained only after the equipment had been in process of "tuning up" for many months. In the 12 months ending Oct. 31, 1908, there were 120 detentions chargeable to the electrical equipment, which detentions totaled 4800 minutes. These include a number of serious detentions due to the 90-mile, 60,000-volt transmission line over which power is received from Niagara Falls for the operation of this road. The record is much better than that of the steam equipment replaced.

Maintenance. There have been no transformer troubles, either on the cars or in the sub-stations. Motor troubles have been very few. No mechanical troubles with the contact wire. The wear on this wire up to August 1908 was from 0.004 to 0.009 in., at which rate it would be between 20 and 30 years before the wire would be worn back to the supporting clips. Stretch of the copper wire and abnormal wear at hard spots will no doubt result in a life materially less than this.

There has been no apparent deterioration of the galvanizing of the messenger cable and other galvanized parts, but such painting as was done on the overhead work has not lasted.

There have been no material troubles or expense caused by locomotive gases.

The life of the pantagraph shoes average about 15,000 miles.

Cost of operation. The operating cost under the usual transportation and maintenance headings of the Interstate Commerce Commission classification, averaged during last summer about 18 cents per car-mile.

It is difficult to make a fair comparison of the New Haven log of operations with a similar log of other existing electrical service. The records of such roads as come under the writer's observation vary widely, and the variations are largely due to conditions independent of the character of the equipment.

Multiple-unit service with trains of more than two motor cars shows up better than single-unit service, owing to the fact that many of the faults of car equipment can occur without causing detentions, the other equipment carrying the train through on time.

Some schedules are operated under conditions well within the speed limit of the equipment, so that time can be made up after a detention. On other roads the schedule is practically up to the speed limit.

In some schedules there is considerable layover of trains at one or both ends of the line, while in others, where the conditions permit and the equipment is worked hard, the layovers are short, and a car trouble cannot be remedied in time to prevent delays, possibly affecting a number of trains.

If trains are operated on short headway, the train in trouble may be helped through by a succeeding train, thus minimizing the number of train-minutes delay, whereas with infrequent service a comparatively insignificant car trouble may show up badly in the log.

Equipment troubles increase with the speed, particularly troubles with the moving contact.

In an analysis of the troubles which actually occur in electrical operation, whether direct current or alternating current, it is apparent that the power station, transmission lines, substations, and distribution system, whether third-rail or overhead, cause but a small proportion of the train detentions. The record of the third-rail is especially good in this particular. Most of the detentions are due to trouble on the cars, and of these by far the largest proportion results from defective control.

In the light of this experience, it is believed by the writer that the New Haven troubles will soon be confined mainly to the locomotives, and these will not be serious. The forced use of the combined alternating-current and direct-current systems is an abnormal burden on this operation. In view of the fact above stated, that is, that most of the train detentions are caused by the control, it may be anticipated that the New Haven operation will not do quite as well in the long run as a straight single-phase service. The use of multiple-unit motor cars will help to improve the log.

The Erie record above quoted, gives no indication that detentions due to locomotive troubles with a straight single-phase system will be materially greater than with the direct-current system.

The maintenance cost is another matter. The greatly increased cost of the electrical equipment of the locomotive or motor-car must necessarily involve greater cost of repair and maintenance. The savings effected in other parts of the system must carry this burden.

W. N. Smith (by letter): The oral discussion of Mr. Murray's paper was so far given over to the particular merits of single-phase railway apparatus, and especially to contrasts between alternating-current and direct-current locomotives, that certain other equally important features of the paper were overlooked.

It was stated that the single-phase motor is the keystone of the system, and controversy upon this feature has been plentiful. The writer submits, however, that although the single-phase motor may figuratively be called the keystone of the single-wire, high-voltage trolley system, the whole system is a means to an end, the end being the minimum cost of motive power which it is possible to effect by means of this system of working conductors.

Comparing the relative amount of dependence placed upon each element of the electric motive power system as a whole, in the last analysis the chief element is the working conductor. In another sense also the working conductor is the fundamental point of departure in a railway system; for in the nature of things it is the means whereby power is supplied to a moving load through a moving contact, instead of to a stationary load as in all other varieties of electric power application. Of the three links in the chain, therefore, the one that is most truly characteristic of railway conditions is the working conductor.

The writer believes it will be conceded by all engineers who have had to carry any real responsibility for bringing a railway line into operative condition, and keeping it there, that the worst interruptions they have to guard against are those due to failures of the working conductors and the power distributing system. That part of the system which is housed in power house and sub-stations, while equally vital in importance with the line, is nearly always present in duplicate, so that failure of one piece of apparatus is quickly made good by substitution, and it is also always possible to duplicate the feeder distribution system; but working conductors, whether trolley or third-rail, are rarely installed in duplicate, and their failure usually means cessation of service until the defect can be reached and repaired.

An examination of the four months' record given by Mr. Murray, as well as records of several other heavy electric traction systems, both alternating and direct-current, show clearly that while the greatest number of train detentions is due to trouble with car apparatus; the detentions due to line trouble or other derangements of the power system are of far greater average duration than those due to car failures.

It is stated by Mr. Murray that it became evident at one time that electrical operation would cease if some change in the contact wire were not effected; but nowhere in the paper is it implied that such a result was at any time impending, by reason of the defects in locomotives or generators. It is difficult to see how greater emphasis could be placed on the necessity for any single element.

As between the merits of the alternating-current and direct-current systems for any given train service on a given road, there is no longer any doubt as to the possibility of determining in advance which system can be installed and operated for the least money; but, with respect to other considerations than those of cost, it is fortunate that engineers now have available the results of the New Haven Railroad experience to assist their judgment in solving heavy traction problems.

Reference has been made to the boldness of the New Haven Railroad in trying such a newly developed system on so large a scale. In the writer's opinion the boldest part of the enterprise was the adoption of a previously undeveloped system of line construction. Unlike the other links in the chain, this one could not be put out of commission for days at a time nor could it be taken into a shop over night and brought out in the morning. It had to be maintained *in situ* over a very frequent traffic and repaired only with the current off, and for the most part from a work train. The engineers who maintained the line in the face of all adverse conditions should be credited with the performance of a task which, however easy to conceive and calculate in advance, was the most difficult to carry out of any, in the maintenance of the whole system.

The means adopted by the New Haven engineers to overcome trolley difficulties seem to have been successful. There is no doubt that the conditions of catenary trolley operation on the New Haven road are so severe, particularly by reason of the frequency of very low bridges, that the fact that there is now a reasonable certainty of continuous operation bodes well for the permanency of the improved methods adopted. Experience on other single-phase systems where traffic and clearance conditions are less exacting, shows that the devices composing the system of working conductors and moving contacts are adequate and reasonably reliable. For railway systems where clearance conditions are severe, and requirements for continuity of service are the most exacting, it is probable that further improvement in mechanical detail of the working conductors and moving contact device will be developed to ensure even greater smoothness of operation. The improvements which experience has shown to be necessary in the manufactured apparatus comprised in single-phase generating and locomotive equipment, seem to have been well taken care of; but the apparently simpler yet more fundamental problem, of improving the moving contact system, still presents a field for the exercise of inventive genius.

Philip Dawson (by letter): On broad principles I agree with the conclusions at which Mr. Murray arrives, in which he pins his faith for general railway electrification, of urban, suburban, and long-distance lines, to the single-phase system. It is the very serious inconvenience possessed by the direct-current, third-rail system which I believe has brought about the introduction of the single-phase system. Had it not been for the latter system, the conditions are such that the directors and officers of the London, Brighton, and South Coast Railway Company could never have seen their way to adopt electric traction, if adopting it had involved the use of the third-rail system.

The form of construction is the double catenary, details of which are shown in Fig. 1. Figs. 2, and 3 illustrate the trolley wire after it has been put up and whilst it is only temporarily supported, before being finally fixed to the clips and droppers which support it from the two catenaries. The droppers are solid sherrardized steel wire, the shorter ones having a loop at each end, the longer ones consisting of two parts looped in the middle. This arrangement gives great flexibility in the vertical plane, whilst ensuring great stability in the horizontal plane for the trolley wire.

The catenaries are of galvanized steel wire cable $\frac{3}{8}$ in. in diameter. Each catenary is independently fixed by means of a turn-buckle and insulator, and supported from a saddle-piece resting on the top of the main insulator. The sag in the catenaries is calculated so as to produce absolute balancing at the supports. The principal insulator has to bear a dead weight which amounts to 850 lb.

All of the insulators are of the best quality porcelain. All of them have been tested, the principal ones to 65,000 volts, and the secondary ones to 25,000 volts for 30 minutes; 10 per cent of the insulators were tested mechanically. The whole construction of the catenaries, girder bridges, insulators, etc., is calculated so as to result in a factor of safety of ten.

The trolley wire itself is round, with sharp grooves at the sides into which mechanical clips fix, and its area is 0.197 sq. in.; its tensile strength being in all cases superior to 22 English tons, per square inch. (1 ton = 2240 lb.)

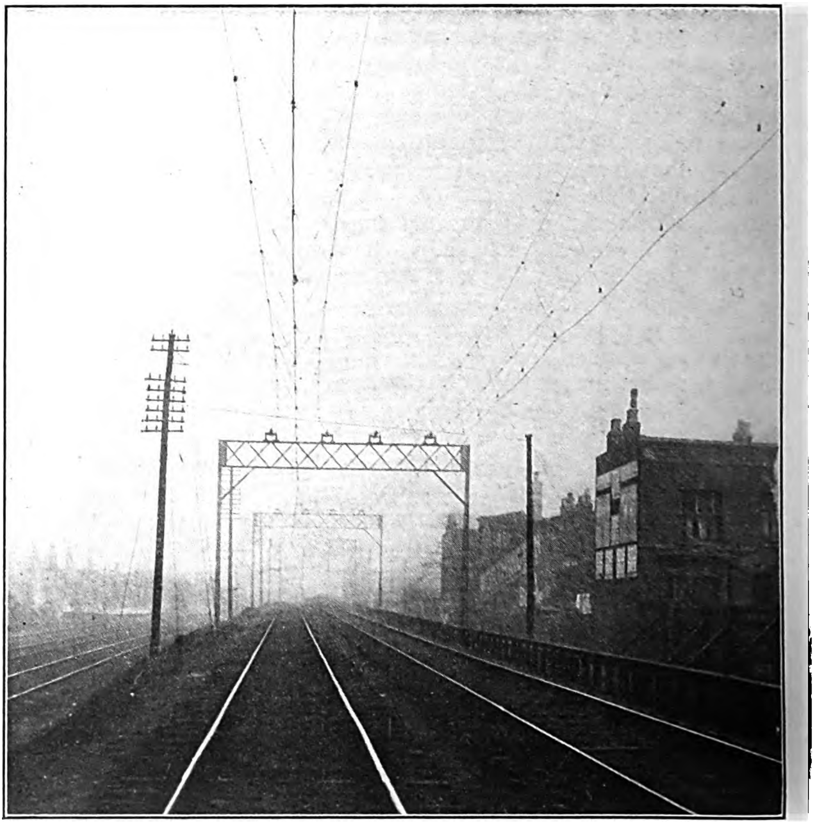

Fig. 1

In order to prevent the hammer blows from which the New Haven line has suffered, the whole construction has been designed so as to make the clips and the droppers from which the clips are supported as light as possible in comparison to the weight of the trolley wire itself.

Three years ago, at the time the London, Brighton and South Coast Railway installation was planned, I made the most careful investigation; and it was then that I decided on the flexible system instead of the rigid one originally adopted by the New Haven line.

The greatest span so far is 195 ft. The vertical projection of the sag of the catenary wire at 50 degrees fahr. for this span, corresponds to 6 ft. Contrary to continental practice, the trolley wire is drawn up and anchored at both ends with due regard for the lowest temperature to which it may be subjected, so that in the coldest weather the elastic limit should not be exceeded in the wire.

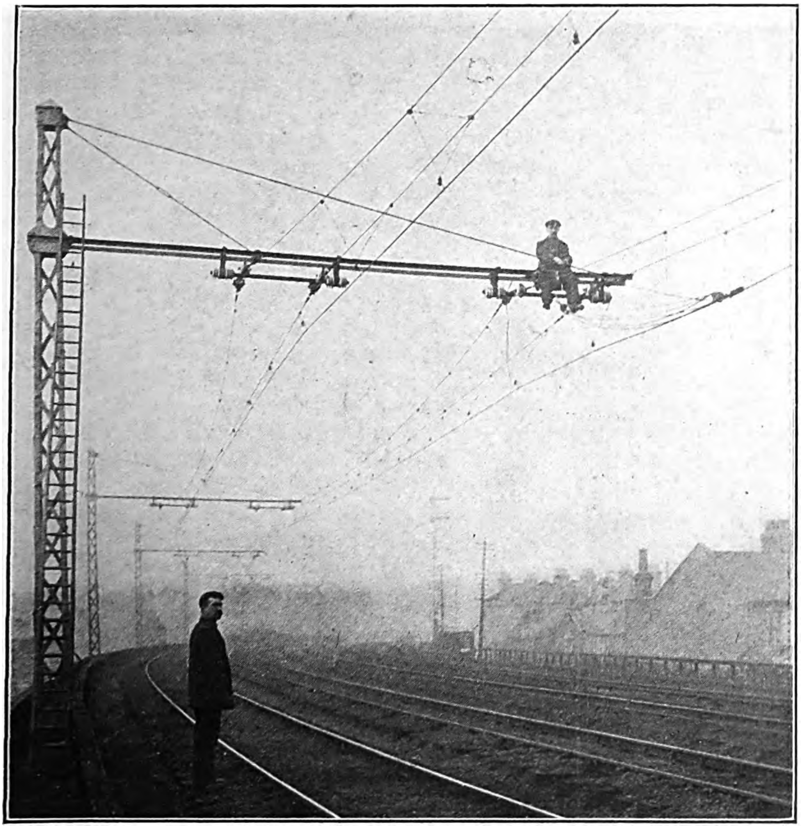

Fig. 2

I have provided for the wire being staggered 18 in. altogether, or 9 in. on either side of the center line of the track, although there are occasions when I have diverted so as to go as far as 13 in. from the center line.

The normal height of the wire will be between 16 and 17 ft., whilst in the two terminal stations the height is 21 ft. At some of the lowest bridges the wire descends to a height of 13 ft. 10 in., or only 4 in. above loading gauge. The train service which will operate over this line at present is of a purely local character, and it is not likely that at the outset a speed of 45 miles an hour will be exceeded.

The extensions that will be proceeded with as soon as satisfactory results are obtained on the first portion now nearing completion may, however, involve the operation, not only of multiple-unit local trains, but of trains hauled by electric locomotives, which of course may obtain speeds considerably higher than that at present contemplated.

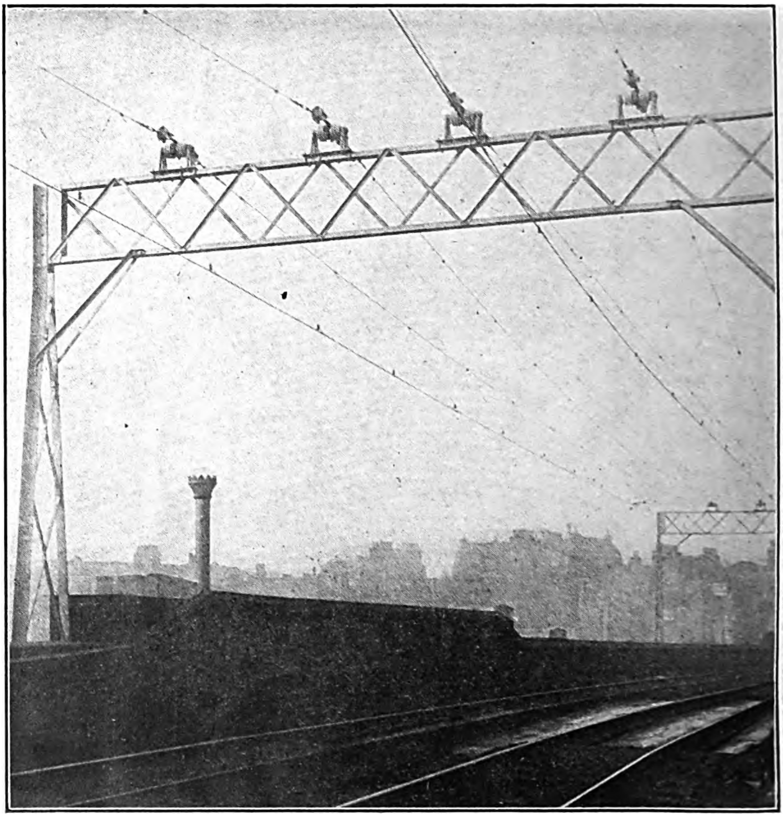

FIG. 3

Careful consideration has led me not to adopt the pantograph type of collector, but to adopt a type of trailing bow collector. This collector consists of a tubular frame, the top of which is fitted with two bows, one forming the rigid portion of the frame itself whilst the other is hinged and sprung from it. It is believed that this method will ensure sparkless running, and operating with a pressure of from 12 to 15 lb. between the collector strip and the contact wire. There are two bows, one for operating in each direction. On the top of the collector bows are fixed renewable grooved aluminum strips, as it is believed that by this means the wear of the wire will be localized on the contact strip, virtually no wear of the trolley wire taking place. Furthermore, owing to the form of strip, and to the low pressure exercised by it against the trolley wire, the cost of the strip itself will not be a very large item in the working expenses.

Ivan Ofverholm (by letter): In Sweden we have had a trial road for testing single-phase details. These trials are now finished and a report made, which I hope will soon appear in American translation. It may interest the Institute to read of some details about our trials, and make a comparison between the experience gained by us and the New Haven officials.

The conditions in our power station were somewhat different from those in the Cos Cob station. We had four-pole generators, running 750 rev. per minute and driven by steam-turbines. In this case the fly wheel effect of the steam-turbine with its gearing (reduction 8500 to 750) was about three times as big as the fly wheel effect of the generator; therefore, when a short-circuit came on, the stresses on the generator axles were so severe that the axles were twisted. For this reason the coupling between generator and turbine had to be made so weak that it would break when severe short-circuits came on. It was also proposed to make a kind of spring-coupling that would allow the generator to slow down when the momentary stress of a short-circuit came on; but as the cost of such a contrivance was considerable, we preferred to make a coupling that did break, but was easily replaced.

In the power station there were two generators but only one circuit-breaker, which at the same time kept the generators in parallel and connected to the line. With this circuit-breaker we have not had the least trouble.

In the beginning there was much trouble with the windings of the generators. They were often short-circuited. At first we thought this was due to some kind of high-potential stresses, and put in protective devices. As these did not seem to work at all, we studied the conditions more closely and found that the coils of the windings were bent in many places. We therefore got the idea that the short-circuits were due partly to mechanical stresses. We put in mechanically stronger insulation in some places where weak points were found; since then we have had no short-circuits in the generators, although there have been several very severe external short-circuits.

It interests me to hear that Mr. Murray thinks the single catenary contact line is just as good or even better than the double catenary. In Sweden we think that a contact line without any catenary is the best, provided the mechanical stress in the contact wire is kept constant at different temperatures, and the bow pressure so adjusted that the resultant stress in the contact wire (the sum of the normal stress in the contact wire and the bending stress resulting from the bow pressure) never exceeds the elastic limit. At present it is not so with ordinary trolley lines. In nearly all the cases we have considered, we have found that the elastic limit is exceeded; the fact that the trolley lines do not come down more often, is due to the fact that copper wire can stand bending above the elastic limit to a remarkable degree.

For steel wire, the elastic limit is sufficiently high, and according to our researches such a wire can keep the internal stresses sufficiently constant at varying temperature without being readjusted. For this reason I think it was a good idea to put up a steel wire as contact wire on the New Haven road, but I wonder if it can stand the smoke from the locomotives. We have had very bad experience in this respect. I know of at least one big installation with steel catenary wires, where these have had to be replaced by bronze wires.

As I have said, we think we can improve the present trolley line construction without catenary very much by using automatically working tightening gear. We intend to make the distance between the suspension-points 25 to 30 metres. But we do not think that we can operate locomotives at high speeds on such a line with only one bow. It is our intention to use two bows placed 6 metres or more apart. The bow has a small (30 cm. high) top bow with little energy, supported by a pantograph. The arrangement we intend to use is an improved form of this bow.

Mr. Murray says that the insulators for supporting the messenger cables had to be doubled up. As far as I can see from Fig. 13 in the paper, these double insulators are placed in parallel. I know of other cases where insulators had to be doubled up, but there they were placed in series. I know from experience that this does not improve the conditions very much. The arrangement on the New Haven road is I think just the thing to be used, as that is the only reliable way by which a bad insulator can be put out of service by itself.

Mr. Murray also speaks of hard spots in the line, and the way to get rid of such things. We have had about the same experience, and therefore we will now make the line as movable as possible in vertical direction, but have it anchored duly in a horizontal direction.

We don't intend to use any deflectors on our lines. We have made many trials in order to see how to get rid of the difficulties at the points where the wires are crossing each other, and have found that all these difficulties can be done away with by placing the wires in the proper position at the crossing.

About the telegraph and telephone disturbances, which Mr. Murray says can be done away with by means of pilot-wires and series transformers. In the case of the New Haven Railroad the disturbances seem to be due chiefly to electromagnetic influence and not of the static charging effect from which our telegraph and telephone suffered so much. This can also be helped, but by other means; these means are mentioned in Mr. Dahlander's report about the Swedish trials.

C. E. Eveleth (by letter): In explaining the failure of the oil circuit-breakers on the New Haven feeders, Mr. Lamme says that the short-circuit current of the generators reached for a few cycles a value of fifteen times normal, which was far in excess of the amount anticipated. Just why this was not anticipated is rather difficult to understand, as machines giving fifteen times normal current, or even twenty times normal current on short-circuit, are not infrequent; in fact, generators that give less than twelve times normal current for the first few cycles when short-circuited are rather the exception.

The oil switch has been generally regarded as a simple piece of electrical apparatus that can be built in almost any form, and still do its work satisfactorily, but experience shows that for successful design and application there must be at hand quantitative knowledge of the conditions to be met.

When associated with Mr. E. M. Hewlett in the spring of 1902 we were impressed with the evidence of enormous current rushes for the first few cycles when generators were short-circuited, and realized that these conditions should be analyzed if we expected to apply protective devices properly. Subsequently we investigated the magnitude of these effects and the action of oil-switches under short-circuit conditions in a series of tests involving several thousand dead short-circuits at various potentials. from 2200 to 75,000 volts, with and without transformers, transmission lines, etc. With the data so obtained we were put in position both to design switches of great energy rupturing capacity and to select the size and type suitable for specific requirements. In some instances this results in a rather more expensive switch than would be advocated by those who have not had such data at hand, and it is not surprising that they continually run into unexpected difficulties.

Simultaneously with the oil-switch tests, investigations were conducted concerning the requirements of reinforcement of the end-windings of generators. It may be interesting to know that in a number of instances we short-circuited individual generators at full excitation from one hundred to three hundred times.

In 1904 it was my privilege to build and test an oil circuit-breaker—which, by the way, did not have a grounded can, and contained less than three gallons of oil—that opened repeatedly on a single break current of 20,000 to 25,000 amperes at 2200 volts. This was equivalent to a rupturing capacity with four

breaks in series, such as would ordinarily be used for a single-phase circuit of over 100,000 kilovolt-amperes. Under these conditions the circuit was ruptured without throwing oil or otherwise damaging the switch, except for some burning of the contacts. As these tests preceded by a considerable time, the selection of the New Haven oil circuit-breakers, and as there are many oil circuit-breakers in service for feeders where the total generator capacity connected to the bus-bar exceeds 50,000 kw. it is apparent that circuit-breakers capable of handling the New Haven conditions had been built and might have been selected. If they had been adopted a large proportion of the serious delays would have been obviated.

The accompanying oscillogram shows the action on one of the short-circuit tests referred to. Attention should be given to the lower curve of Fig. 1, which shows a rise to more than double potential in the voltage of the phase not short-circuited. As this potential strain would be applied to all of the polyphase apparatus on the system, and furthermore as there exist at all times badly unbalanced voltages whenever one phase is loaded more than another, especially with inductive load, and the voltage maintained by regulator on the loaded phase, there are some manifest disadvantages in trying to operate single-phase and polyphase apparatus from the same generator. For this reason it is my opinion that such operation is at a decided disadvantage as compared with straight single-phase operation on an undertaking of the magnitude of the New Haven system. I think it would have been better to supply separate polyphase generators for operation of shops and direct-current sub-stations.

W. S. Murray:* In connection with the discussion contributed by Mr. Townley: It is a pleasure to record the number of interesting points that he has brought out which the paper did not include. As I have been accused of being over-enthusiastic about the New Haven electrification by one author of a discussion, and Mr. Townley has seen fit to feel that I am not sufficiently proud of it, between the two I am able to average a happy medium. As a matter of fact, my pride was inclusive of being willing to make a complete exposition of the difficulties, and in reviewing the paper, while recalling the many successes that could have been mentioned to offset the temporary failures, my mind constantly dwelt on the belief that " our friends ", who were so freely disporting themselves in the general condemnation of the system, were entitled to the actual facts of the situation. In this " deed of gift " I constantly steeled myself against introducing any ameliorating features of success in the system, for fear some slight prejudice would come to their minds. Indeed, I will never be quite able to determine whether the cause of the sudden secession of this voluble condemnation was due to their possession of these facts, or the reliability of train schedule on the New Haven system, which arrived about the same time.

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* The closure of the discussion was written about four months subsequent to the date of the paper.

In reference to the discussion of Mr. H. P. Davis. I am exceedingly glad that he has included so much detail in regard to the general operation of the distribution system. The fear of giving the paper too great length constantly suggested caution in digressing too far from the trunk-line principles involved, and as stated in the closing paragraphs, it was the author's hope that the details of construction and operation would be brought out by the discussion. Mr. Davis has brought out clearly the electrical and mechanical operating characteristics of the distribution system, and it may be said that except for the fact that the multiple arrangement of overhead wires in the distributing system brought about such an exceedingly high conductivity, the circuit-breakers would have functioned entirely in accordance with their anticipated plan of operation. The lowering of the current density on the occasion of short-circuits by the actuation of the auxiliary apparatus described by Mr. Davis has accomplished the degree of selectiveness which was the first aim in the conception of the system.

In connection with this type of distribution system, employing a voltage of 11,000, this is an opportune time and place to point to a suggestion that comes from the mouth of experience. While I do not think it is by any means impossible to design generators of the voltage and capacity, as installed in Cos Cob station, to withstand the shocks of short-circuits of the character that have been received by that station, the form of protective apparatus that has been installed to alleviate the electrical and mechanical strains incident to these short-circuits, certainly suggests the wise expedient of designing a low voltage (say not greater than 2300 volts) station, employing static transformers to secure the higher transmission voltages, and it is to be noted in connection with the softening effect, as a result of the transformers being between the generators and the line, the increased cost, due to transformer equipment will be offset by a lower price per kw. of generators and switchboards, due to lower voltage and, further, that what loss may be suffered in virtue of the introduction of transformers will be greatly offset by the higher efficiency accruing from a low, instead of a high-voltage generating system. I believe in connection with single-phase electrification, this arrangement in power house design should be effected.

Referring to Mr. Torchio's discussion and in answer to his three questions:

1. Concerning the grounded circuit-breaker frame. If the frames of the circuit-breakers were supported upon insulators, this would approximate the ordinary or ungrounded system conditions; that is, where no phases are grounded. But the earth not being an insulator, and as the frame of the circuit-breaker rests on metal (anchor) bridges, as explained in the

paper, this brings one terminal of the generating system directly to the circuit-breaker frame; hence, the necessity of strong *lining* insulation. If the frames of the circuit-breakers were ungrounded, this would introduce danger in handling the switches; as it is not impossible to conceive of a connection being made between one of the switch points within the tank, and the iron tank itself, upon which occasion, should an attendant be standing on the ground and touch the tank, he would be shocked. By the present arrangement of grounded circuit-breaker tanks this hazard is obviated.

2. Three-phase generators are used in order that power may be supplied to the polyphase motors operating in our power house and in shops adjacent to the line. Polyphase current will also be used in operating direct-current railway plants, whose prime movers, at present, are steam engines, which will, later, be replaced by polyphase motors.

3. Concerning the regulation of single-phase *vs.* 3-phase generators, it is quite evident that the use of single-phase generators would do away with the unbalanced conditions that obtain in the case of the 3-phase generation. However, the amount of unbalancing is extremely small, due to the copper-clad rotors on the generators, and, further, had single-phase generators been used this would not have permitted the advantages of power house, shop and railway plant drive, as described above.

In connection with the interesting discussion that Dr. Steinmetz has contributed, it is pleasing, indeed, to note his prediction that when the time arrives to electrify our transcontinental railways, the alternating-current single-phase motor will be the ways and means. His commentary on weight efficiency suggests a thought which I would venture supplementary to his reference to drawbar pull *vs.* weight of motor. I think it is wise to guard against the exclusive rather than the inclusive view. Given two terminals, say, 12 miles apart, between which electrified tracks are to handle a given traffic, if the fixed charges and operating expenses per ton mile are the same for either the alternating or direct-current systems, it is undeniably true that we can not escape the conclusion that the direct-current type of motor, on account of its lesser weight per pound of drawbar pull would be the legitimate and logical selection of motive power, or in other words, all other considerations of the system being equated, these and only these are the circumstances under which the matter of weight efficiency is a ruling factor. Where we are considering 50 or 100 miles of dense trunk line operation, the weight efficiency, though having a bearing, takes its position along with the other considerations, but is assigned a proper degree, which becomes exceedingly minor in the consideration of heavy mileages and heavy power requirements. In charging up the alternate-current motor with more weight per drawbar pull than the direct-current motor, the difference can be represented in dollars and cents, but we must not end the investigation where it has just begun. The 12-mile railroad, above described, may have its power station at its center, and its traffic sufficiently light to require no rotary sub-stations, and possibly not very much copper in its distributing system. The situation takes on an entirely different hue, however, in making a decision upon the 50 or 100-mile heavy traffic proposition. If direct-current propulsion is to be used, this will require sub-stations and with it many pounds of low-voltage copper feeder. These items of sub-stations and feeder copper, like the increased weight of the alternating-current motor over the direct-current motor, cost money and must not be forgotten, and so when we formulate weight efficiency equations, while we are not forgetting to charge up the cost of the greater weight for the alternating-current motor, let us not forget to charge up the cost of the copper and sub-stations complementary to the direct-current installation. Outside of all this comes the careful consideration of the system's commercial efficiency, better stated as the ratio of operating expense to gross income and, therefore, except that weight efficiency be considered inclusive and charged with its relative value of importance in the system as a whole, its importance is only apparent and not real.

In reference to Mr. Minor M. Davis's contribution concerning the effect of single-phase currents upon telegraph and telephone wires, I would further supplement my remarks on this subject which I made on the occasion of its reading before the Institute, and say that it was the effort of the author to touch as briefly as possible upon the electrification, in its relations to matters other than traction. Each one of the subjects mentioned is one upon which much interesting matter, in detail, could be brought out, and in this effort at brevity I was conscious of the fact that this particularly important subject might have been treated in greater length. Too much credit cannot be given to the companies adjacent to our property, who were affected by our lines, for their coöperation in which both their efforts and our own were united to overcome the disturbance. As I review the two paragraphs upon this subject, I do not see any occasion to modify the statements that have been made, except to say that possibly Mr. Davis's position enables him to better judge of the cost of the transforming equipment necessary to effect the voltage compensation described.

Mr. Lamme is the father of a practical single-phase motor, and has brought to himself another responsibility in the nature of the dampened field 3-phase generator, which has been so well described in his discussion. However, as progenitor of these two types of apparatus, only the greatest satisfaction can come to him, in view of the uniform good behavior of both, thus making the new responsibilities at once both heavy and light. I am particularly indebted to him for the generous detail in which he has described both of these types of apparatus. Four months have elapsed since his discussion was written, and the short-circuit disturbances that occurred in the generators then described have since disappeared, and the mileages of the motors instead of the figures as stated by Mr. Lamme have become in some instances as high as 70,000 miles; the average mileage of all motors being probably 60,000 miles, and this with 60 per cent of the commutators still unturned. As a matter of fact, and as Mr. Behrend has pointed out, the operation on both alternating and direct-current power is very much alike as far as sparking is concerned, and as the number of miles over which a commutator operates before it is necessary to place it in the lathe for turning, is dependent almost entirely upon the degree of fineness with which it commutates, and as the mileage, as stated, is comparable with the ordinary direct-current practice, it is fair to assume that it is a matter of indifference whether the motor is commutating alternate or direct current. Mr. Lamme's interesting statements in regard to the strains produced in the coils of the Cos Cob generators on the occasion of short-circuits, leads me again to one of the fundamental reasons for the low-voltage generating station with step-up transformers. It cannot be denied that a short-circuit on a system of high conductivity produces an enormous rush of current. As previously mentioned, the interposition of the transformers between the line and generators offers a cushioning effect for this blow. Added to this valuable adjunct of protection, is the fact that in the low-voltage-wound generators the coils naturally increase in cross-section in proportion to the ratio of diminished voltage, that is, for the same output and the same number and length of coils, a generator of 2300 volts would be wound with coils whose cross-section would be 4.75 times the cross-section of the coils of an 11,000-volt generator. Thus the coil itself is inherently a strong mechanical device for resisting these strains, and, further, its tendency to puncture is greatly reduced on account of a reduction in potential between copper and iron in the ratio of 4.75 to 1.

In connection with Mr. Stillwell's reference to errors in generator and circuit-breaker design, I think Mr. Townley's statement that the " . . . one radical thing that was done wrong in the New Haven electrification, and which was really at the bottom of a large part of the difficulties that have been encountered is that the electrification was not begun soon enough ", is a complete and decisive answer on this commentary. Seldom, if ever, do we see the manufacturer test at the factory, generators larger than 2,000 kilowatts at full load and full voltage, simultaneously. Rather do they elect to provide these two conditions separately, and accomplish virtually the same result, using only 5 per cent of the power that would be required in the former case. Similarly with the New Haven, it would have been quite impossible to have duplicated the operating conditions in the case of the generators or circuit-breakers. A temporary duplicate test system was impossible. The test would have been made on the original apparatus had it been possible, but time was not available, as has been pointed out in the paper under "electric passenger service", in which an attempt was made to describe the pressing force that was constantly brought to bear on the New Haven engineers to begin electric service.

It is a pleasure, however, to read Mr. Stillwell's commentary that the four month's record of operation, as presented in the paper, was not a discouraging one, in the realization that the average for the train-minute delays during the last five months are 13½ per cent of the average of the four months cited in the log.

In response to Mr. Behrend's question in regard to the use of a 2-phase rather than a 3-phase generating plant, as applied to the New Haven conditions, I think this is a point deserving of a very careful explanation. Power house location has much to do with the choice between these two systems. In the case of a 2-phase system, it is natural to suppose, in order to secure the highest copper efficiency, that the point of divergence of the two phases should take place at the power house, if the power house is on the line of the railroad. Examining the location of the power house in the case of the New Haven, it is to be noted that about 18 miles of track lie west of the station, while about 3½ miles lie east of it. Thus it is quite clear that had the station been designed for two phases, they would have been very much unbalanced, especially as the train density is heavier per mile of track on the longer section, which, of course, would be a very unfortunate distribution of load in the windings of the generator.

In the operation of polyphase motors for shops and for street-railway-station drive along the line of the railroad, it would be necessary to intermingle the two phases of the system using the track for a common return of the currents of the two phases in quadrature. This would not introduce any features that are distinctly inferior to the present arrangement of the three phases throughout the length of the system. The question of voltage regulation for a 2-phase distribution, however, offers a decidedly serious aspect, as it is quite clear that it would be impossible to keep the voltages of both phases constant, unless the load on each was always the same. In the case of the 3-phase, we regulate the voltage of the propulsion phase, and the copper-clad rotors of the generators smoothes out to a great degree the unbalanced voltages on the two other phases. I believe the deciding points against the 2-phase propulsion are the difficulties incident to loading the phases equally and maintaining voltage regulation.

The relative temperatures due to operation on alternating and direct-current, to which Mr. Behrend refers, I regret have not been obtained. The conditions of operation on the alternating-current zone and direct-current zone are so absolutely different that a comparative set of figures would be impossible, unless they were obtained under the auspices of test conditions. Later, this information may be obtained and will be gladly offered.

I note by Mr. H. F. Parshall's contribution that in 1901 he was appointed by the Board of Trade a member of the tribunal, presided over by the Hon. Alfred Littleton, to determine whether or not such an alternating-current system, as proposed by Ganz, was suitable for the underground railways of London. Immediately follows his conclusions that the alternating-current system was unfit for application upon the aforesaid railways, even though this date was previous to Mr. Lamme's paper on the Washington, Baltimore and Annapolis single-phase railway read before the American Institute of Electrical Engineers, at New York December 26, 1902,* which might have been said to be the entering wedge of the single-phase motor in its application to the propulsion of trains. Engineers of this country would surely look for a few grey hairs on motors of any design existing over a period of eight years, and so I do not wish to be counted out in the first ranks to congratulate Mr. Parshall in this eminent decision, which sounded the death-knell to the alternating-current motor for the subways of New York and the underground railways of the City of London. The London and New York subways offer about as much comparison to the New York, New Haven and Hartford Railroad Company's conditions as a steamboat does to a flying machine, and so I must leave this subject abruptly, and pass to a few concrete statements, which Mr. Parshall has made, and which seem to have been arrived at by projected hypothetical curves. A few brief counter statements may save time. The perfected alternating-current motor does not weigh 40 per cent more than a direct-current motor of the same capacity. If the air-gap of the alternating-current motor is of a character which permits the revolution of the armature in its bearings, and requires no greater maintenance than the direct-current motor, it does not matter how much smaller it is than the direct-current motor air-gap. Higher armature speeds are a specific advantage rather than disadvantage, in view of this characteristic having excellent application to the direct-connected type of locomotive. Our experience, though possibly not as great as Mr. Parshall's, does not prove that the cost of the high-tension overhead system properly installed is greatly in excess of a third-rail system. It is possible that the overhead wires and bridges necessary to carry them may cost more than the third rail, though even these may be equated. I can even conceive of the overhead contact construction on an alternating-current system being more expensive, *per se*, in first cost, and yet more economical in use, thus again we have this unfortunate feature presented of only looking at a part of a system instead of its whole.

The alternating-current commutator is in itself heavier than the direct current, but practice and experience in this case has not substantiated Mr. Parshall's theory that the maintenance " ..... is nearly double that of a direct-current equipment of like capacity ". A few facts scattered in this nest of hypothetical reasoning may be useful, one among the number being that our present operating sheets show that our operating costs, *per se*, on the direct-current zone are just 40 per cent greater than that of the alternating current. At the time of presenting the paper on the " Log of the New Haven Electrification " it had been in commercial operation just four months, and I cannot refrain from quoting the last few lines of Mr. Parshall's discussion: " Concerning all that has gone on in the New Haven system up to September 5, 1908, which appears to be the termination of Mr. Murray's log, there is absolutely nothing to indicate that during 1909 some such series of occurrences are not again to be expected. All that has occurred may be expected to occur again in some form or another, since electric traction apparatus does not manifest all its faults during the first few months of operation ". Is not the first commentary upon this closing, encouraging eulogy a disappointment, that one is willing to make up his mind to condemn a system four months after its birth? Is this not a brief period during which to compose its obituary? Secondly, I can only say that " All that has occurred " *has not* " occurred again ", and whether it will in " some form or another " is so closely related to indefiniteness that analysis itself is duped, and prophesy becomes a helpless paralytic.

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* Transactions, vol. xx, p. 15.

Mr. Armstrong opens his discussion with the following startling sentence, which contradicts everything that follows. " The enthusiastic coöperation of the engineers of the railroad company and the manufacturing company has brought this alternating-current operation to its present success and nothing but admiration can be expressed for the courage and ingenuity shown in overcoming the difficulties met with in operation ".

In thanking Mr. Armstrong for thus felicitating us, I am sure I will be pardoned for the number of exceptions that I must take to his subsequent remarks, in view of their almost complete inconsistency with the facts.

1. The New Haven specifications, as doubtless looked over by Mr. Armstrong, were drafted to make them inclusive of the operation of electric locomotives from New York to New Haven. The installation, therefore, of the alternating-current system of propulsion was not to *demonstrate* the suitability of that system to possible future extension of the road. It so happens that it has accomplished this purpose, but this is off the point, and the interesting feature of Mr. Armstrong's statement in the second paragraph of his discussion, is his full commitment to the 600-volt, or the 1200-volt, direct-current system, as the system applicable to the New Haven conditions, inclusive of the zone above described.

It is interesting to note the seeming pleasure in which Mr.

Armstrong points to the "material changes" that were made to the locomotives and the generating and distributing systems. Following upon this is his statement of Mr. Wilgus's report of the cost at $55,000 a mile of our overhead construction. Why bring in Mr. Wilgus? Mr. Wilgus had nothing to do with either the estimates or the checking of them in actual practice. It is difficult to conjecture how he even arrives at these figures. Also how is this relevant to the paper? It does not discuss costs.

2. This inconsistency comes to mind in viewing Mr. Armstrong's guesses on the weights of the locomotives. These are completely without foundation.

3. Mr. Armstrong refers to published figures on the trolley construction, which as a matter of fact have never been published, not to mention inconsistency No. 4, in which we find Mr. Armstrong increasing the weight of the locomotives 50 per cent, for which he has absolutely no basis, and in which statement he is again absolutely wrong. Mr. Armstrong advises that the present weight of our locomotive approaches fairly close to the weight of the locomotive which he estimated would be required to perform the service originally specified. Doubtless Mr. Armstrong's experience in the design of alternating-current locomotives would have permitted us to make a closer approximation. It has never been my pleasure to have seen an alternating-current locomotive of Mr. Armstrong's design, though this does not preclude the possibility of one being on the rails. The only sure conviction I have, however, is that neither he nor his associates offered to design one which, with an amount of capacity equal to that of New Haven locomotive, was lighter.

I confess to a slight agreement with Mr. Armstrong's statement that the object of the New Haven electrification was of a far-reaching character—at least, far enough to reach to New Haven. How Mr. Armstrong can commit himself to such a statement that the New Haven trolley construction costs 80 per cent more than the 600-volt third rail, and that the locomotive costs double the amount of a locomotive sold another company, without even a film of foundation for his statements is really remarkable. To deny them flatly is, I judge, sufficient. Such remarks draw one almost to the necessity of discussing comparative figures of the one system with the other, as it is not to be denied either within or without the ranks of the two companies interested, that the New Haven road knows the investment costs and operating expenses of both systems. Some day the dictates of progress may demand an exposition of these facts, but they can not be drawn out by baseless innuendoes of the character above cited.

Mr. Armstrong's tables in reference to weights and horse powers of the New York Central and New Haven locomotives are wrong, in respect to the data he assigns to the New Haven columns. Again we have the brilliant reference to the 1 hour performance of the locomotives, completely ignoring the continuous capacity for which the New Haven locomotives were designed. This is not better exemplified than in the table that follows, showing the list of train weights above 400 tons which the New York Central locomotive has handled. The table would have been more useful to an engineer had an asterisk been attached with the notation that none of these trains were hauled to a distance greater than 12 miles.

To Mr. Armstrong's generous offer that I correct any error concerning the New York Central company's train-minute delays in view of my access to their official records, in the table which appears on the closing page of his discussion concerning the train-minute delays on the two systems for the months of July, August, September and October, 1908, I would say that were an error discernible, I would trust that it would prove the train-minute delays less than the number he has cited. I will refrain even from checking Mr. Armstrong's statement of train-minute delays he charges for the New Haven system over the same interval. My acquaintance with the officials of the New York Central company leads me to believe that they regret this form of argument which Mr. Armstrong advances, knowing that their system, incorporating the principles of 20 years' experience, and in operation one year previous to that of our own, should be compared with the first four months of a system whose lines were so radically different from their own, and whose principles were of such an entirely different character. It is interesting to note, however, that the average for the train-minute delays during the past five months following the four months cited in the paper are 13½ per cent of the average during the period of operation the paper includes.

Since Mr. Armstrong's desire to compare operating statistics has crystallized into the train-minute delay table which he has published, doubtless a reply more to the point of his argument would be the statement of the fact that notwithstanding the main line New Haven electrification is inclusive of both alternating- and direct-current operation, with an average of 135 trains a day, the actual number of train-minute delays during the whole period of operation since 100 per cent service has been under electrical control, has not been equal to the train-minute delays that are charged up against the two straight alternating-current cars operating upon the New Canaan branch during two of the four months cited in the paper. I feel justified in making reference to this fact, in order to substantiate Mr. Armstrong's opposition to the single-phase situation, for on this branch the equipments are of a design better known to himself, but I am happy to be able to record the fact that our position is fortunate in that should the New Canaan situation fall a victim to a policy which I understand is being advocated, we will not have to *go back* to the direct-current form of propulsion.

While the intent of the paper did not include a desire to compare the electrification of the New Haven with that of the New

York Central, it seems that this phase of the situation developed in the discussion, and Mr. Storer has offered some very pertinent and interesting inquiries, the answers to which doubtless will come later. The most interesting part of his discussion to me is the emphasis he lays on the necessity of making system comparisons rather than the comparison of the individual parts of systems to each other.

It is very interesting to note Mr. Lyford's statistics in regard to wear on the contact wire and to note his prediction of a life of between 20 and 30 years. This corroborates micrometer measurements made on the steel wire during the past nine months of operation.

I have been very much interested in Mr. W. N. Smith's analysis of the situation, and I think he has placed his finger upon the keystone of the arch of successful alternating-current operation when it rests upon the overhead line. As stated in the paper, the three great links in the chain of electric propulsion are the power house, line and locomotives. As Mr. Smith has pointed out, power houses and locomotives may be relayed, but the line must stand alone, at least over a specified single piece of track. His analysis is to the point when he shows that the train-minute delays were the greatest in duration when occurring by reason of line failures. It was with this point in view that the author of the paper made the statement that, "In the month of May, 1908, it became evident to us that within at least one month from that date, if some change was not effected in the contact wire, the New Haven electric service would cease." But by far the most pleasing feature of Mr. Smith's contribution is that with finger pointing to the single link that had to be intact to ensure electric service, and while assigning it to its great degree of importance, his mind dwelt at the same time upon what the whole system stood for as a means to an end, and which must have been inclusive of safety, reliability of service and economy of operation.

Mr. Phillip Dawson's contribution to the discussion, in the form of the description of the London, Brighton and South Coast Railway Company, which uses the overhead single-phase system, is of much interest. It is to be noted that on this construction the spans are very much less than in the New Haven. To me the most interesting piece of metal in the overhead system is the contact wire, and I note that on the London, Brighton and South Coast Railway, the trolley wire is drawn up and anchored at both ends. It is quite possible that the clips Mr. Dawson has described as supporting the contact wire will be sufficiently light to prevent kinking at the hanger points. This arrangement will be greatly fortified if, as Mr. Dawson states, speeds of 45 miles an hour will not be exceeded. The double messenger triangular form of hanger offering a more rigid form of construction, and a greater degree of inertia at the hanger points, shortly proved itself undesirable for the speed conditions that exist upon our lines, and I feel quite sure that even in the form of single catenary suspension, our conditions would not permit the form of construction as adopted and described by Mr. Dawson. In short, our experience with the overhead construction leads me into the following brief specification for an overhead contact wire.

1. One single steel stranded messenger cable with deflection corresponding to economical values fixing distance of span.
2. One horizontal solid copper conductor supported from steel messenger at intervals of 10 ft. with light tension on same.
3. One horizontal solid grooved steel (contact) wire supported by light clips (weight not greater than 9 ounces) from the solid copper wire at mid-points between messenger hangers. The tension in this wire not to exceed the elastic limit of the steel at lowest temperature.

This auxiliary or contact wire as described under (3) it seems to me, has as much right for existence as the floor of a highway bridge. To make contact on the copper wire, would be the same as running on the members of a bridge, which, while consistent with the past practice of the electrical engineer does not match up with the precedent established long before the electrical engineer had to design his bridges for electrical traffic. The steel wire offers a cheaper and more easily replaced floor, and the conductor system always remains intact with undiminished efficiency.

The double-bow pantagraph collector with renewable contact strips has been tried out on the New Haven system. We did not get a very great deal of encouragement out of this form of collector; however, with the varying heights which highway bridges have dictated the contact wire to be, and with a continual deposit of steam locomotive discharges upon it, not to speak of the very high-speed conditions our collectors are subjected to; these may possibly have qualified the success which I only trust will accrue in their use on Mr. Dawson's road.

In answer to Mr. Ivan Ofverholm's inquiry in regard to the effect of smoke of the locomotives on the steel contact wire, I would say that our experience in connection with this deteriorating influence that the electrification has to contend with at present, is not so great as I had anticipated. A careful observation on the steel wire during the past nine months does not indicate that the blast from the locomotives has had much, if any, effect.

In connection with Mr. Ofverholm's statement concerning the doubling up of our messenger cable insulators, I see that he has referred to Fig. 13 descriptive of the yard construction. He is quite right that the insulators in this case were placed in parallel. On this occasion, however, this arrangement was made in order to resist mechanical rather than electrical strains. The strain in the cross catenary, which supports trolleys over 10 tracks, is 14,000 pounds. To-day porcelain insulators capable of resisting a mechanical strain of 40,000 lb. and 40,000 volts are at hand, but it was decided that single insulators of the character shown in the picture, which were the only ones then available, would not be sufficient, with proper margin of safety, to withstand this strain, and a special yoke was constructed upon which were installed the two insulators, to which Mr. Ofverholm has referred. A reference to Fig. 8, though not as clear as if the picture had been taken closer to the insulator, shows two insulators of the same type in series; this being the arrangement throughout the system over the main line tracks where they are subject to the blast of the steam locomotives.

Concerning Mr. Eveleth's suggestion that had we adopted the circuit-breakers of his design a large portion of the serious delays would have been obviated; even granting that his circuit-breaker would have functioned in the exemplary manner described, I feel sure that the oversight in not having adopted it will be excused in our having considered it a part of the detail to be supplied by a company which believed *first* in the system, before they believed in the circuit-breaker. We may yet have an opportunity to use some of Mr. Eveleth's circuit-breakers though I doubt if the results can at present be bettered.

DISCUSSION ON "PRIME MOVERS," NEW YORK, FEBRUARY 19, 1909.

(Subject to final revision for the Transactions.)

The President: This is a subject in which we all are vitally interested. There probably has been more done in the last five or six years in the development of prime movers than was accomplished in the previous 20 years. This serves to emphasize the importance of considering the question of depreciation in the broad way in which the author has approached it, and I wish to call attention to the happy manner in which he has expressed it. As an illustration of the truth of what he has said, I might cite something that may be of interest to you.

It is now six years ago since the largest steam-turbine powerhouse was completed in this country. There were at that time four turbines installed. Thirty days ago there was begun the dismantling of the first of these four turbines. That is a very short period of time in which to have had the turbine installation in use, but it bears out exactly what Dr. Steinmetz has said in his paper. The economy of the present turbine, compared with those which were installed six years ago, has so improved, that it pays the company to scrap the turbines it put in at that time, and install new ones of a more modern type; in other words, the saving to be effected, due to the increased economy of the new turbines, when capitalized, will more than pay for the cost of the new turbines. Not only has the economy of prime movers been improved, but their reliability as well, both contributing to place the production and marketing of electricity and electrical apparatus on a more firmly established basis. This appeals, naturally, to those of us who are engaged in the operating department of engineering, carrying with it the great responsibilities not only to investors but to the general public, whose servants we really are, and we appreciate most highly the interesting and instructive manner in which the author has brought out the necessity for considering in all statements of cost, the value of reliability.

Charles E. Lucke: It seems to me the first part of this paper is mainly a repetition of many elementary facts almost axiomatic, in which the only idea that strikes me as new is the proposition concerning reliability insurance. That seems worth while. As to the rest, I confess I am distinctly disappointed, especially in relation to the thermodynamic efficiency part. I have studied things of this sort a good many years, it is my own specialty, and it may be that I expect too much, but one fact I cannot overlook in this thermodynamic efficiency analysis, is that thermodynamic efficiency, as it is taken up in the paper, referring only to the cycle, depends primarily on two things (*a*) the nature of the cycle, that is to say, the sort of phases and order of succession of the phases or processes, to use a better word, and (*b*) the extent to which each phase is carried.

The order in which the processes are carried out will affect the efficiency, in fact it will determine it, with one exception, and that exception is the equation of condition that fixes the extent of the phases. If it is desired to adiabatically compress or heat at constant volume, the nature of the process is defined, and that is the first step in fixing the possibility of the cycle, the next step being, how much heat is added or how much the gas is compressed. What fixes the thermodynamic efficiency of the cycle, as such, is just these things: the nature of the processes, the order of the succession, and the extent of the heating, the expansion, cooling or compression.

The author has assumed certain cycles, which are very well known and which have been studied repeatedly, and which are in nearly all the elementary books. The study of these cycles is proper subject matter for a third year course, such as we have at Columbia, or, in a not very advanced institution, for a fourth year course. The author has assumed certain limitations to the extent of certain phases, by fixing pressures and temperatures, purely arbitrarily, and the results and conclusions are worth no more than the assumptions. Any other assumptions that any one else considers reasonable will bring other results, and we might have endless controversy concerning the conclusions. Every man's conclusions would be as good as the others so far as one set of assumptions is as reasonable as the other.

The author has fallen back in two or three places on that old statement in every text-book, which is generally misunderstood: " The thermodynamic efficiency is essentially a function of the temperature difference, on which the engine operates." This is a variation on the statement of the Carnot cycle law, which is ordinarily set down as follows. That the maximum efficiency obtainable for a given temperature range, is fixed by a certain expression, usually $\frac{T_2 - T_1}{T_2}$. As a matter of fact the actual efficiency of any cycle has very little to do with this, has no more to do with it than my income has to do with the wealth of the nation, although the wealth of the nation certainly limits my income. It is quite true that Carnot's cycle yields an efficiency which is the highest possible for the temperature range, and it is likewise true that no gas cycle comes anywhere near the Carnot limit.

We are especially concerned with the gas cycle. The efficiency of any gas cycle is not a function of the temperature range, it is a function of, the nature of, the order of succession of, and the extent of each phase making up the cycle.

As engineers what do we care about the temperature range anyway? Do we approach the gas engine, the question which Dr. Steinmetz has finally interested himself in, by saying let us compress this gas to a certain pressure, and then have a constant volume rise to a temperature of 800 degrees cent. or

700 degrees cent., or 900 degrees cent.? We do nothing of the sort. We put into the gas mixture as much heat as we can, and do not care what the resulting temperature is. We put just as much heat into the gas as we can, to do as much work as possible in the cylinder, and the maximum temperature nobody knows the value of nor cares about. We do know how much work we can get, how much efficiency we can get, and also, that it has nothing to do with the temperature range.

It is possible, by taking proper assumptions for all variables by setting up mathematical or other criteria by which to judge these results, for each man to arrive at results in his own particular way, and all different. If you will go through the literature on the subject you will find laws enough derived in this way to prove almost anything. Such cyclic analysis is almost as valuable as the Bible to prove things. An expression can be found to prove almost any statement, and another one to disprove it. Change the assumptions, always keeping them within the range of what you can induce some one to say is reasonable, and contradictory results can easily be obtained. I think as a consequence of this situation that this analysis of thermodynamic efficiency is not very valuable.

I have been carefully looking through the paper—for a conclusion. I have been trying to find out just what Dr. Steinmetz was trying to show, to throw, if possible, some light on the assumptions he uses, and I have not been able to find any conclusions. If the conclusion is that the gas engine cannot have as high an efficiency as the steam engine then the conclusion is absurd.

Henry E. Longwell: The opening sentences of Dr. Steinmetz's paper constitute a cheering message to those of us whose daily bread depends on the continuance of a demand for prime movers. When one who is not, and who cannot hope to be versed in the intricacies of electrical science, hears and sees evidence of what he imagines to be mechanical work done by that phenomenon which we call lightning, he perhaps should not be too harshly criticized if he should have conceived the idea that electrical energy does exist in nature. It is not improbable that the school-books of our childhood days are largely responsible for the inculcation of this disquieting idea in the unsophisticated mind. By their persistence many of us have been led to unconsciously accept as classic, the crude experiments and deductions of that archaic philosopher and physicist, Benjamin Franklin.

During a life which is still a little inside the alloted span of three score and ten, I have seen so many impossible things happen, that for my own part, I am pretty well content to keep an open mind on all questions bearing on ultimate possibilities.

One can readily imagine a perfectly flat country, where the inhabitants could have no conception of hills and waterfalls. Such a country might be abundantly watered by lakes and canals, and yet one could forgive the wise men of this hypothetical nation if they asserted that water power was not found in nature; that water power could be available only through the kind offices of a prime mover that would convert the energy of fuel or of air currents into mechanical rotation or reciprocation, thus producing an artificial head or pressure that would enable the water to do work.

Considering the marvelous developments in electrical science during the lifetime of even the youngest member of this Institute, is it safe to set a limit to the possibilities of centuries yet to come? May it not be that we are now coming ourselves only with electricity as a *medium* for the transmission of energy? We can with certainty and precision produce by mechanical agencies, a difference of potential which enables this thing we call electricity to reproduce in a large measure the energy expended upon it. But does this fact make absolutely unthinkable the proposition that there may be natural differences of potential, yet undiscovered? However, with the authoritative assurance that we can never hope to eliminate that troublesome yoke-fellow of the electric generator, the prime mover, who alone prevents the business of operating an electric power plant from being a rapturous dream of profit and pleasure, we can, with all the more satisfaction and determination apply ourselves with renewed vigor to the task of reforming him.

As regards the determination of costs of electric power, this is not essentially different from cost accounting in any other industrial enterprise. Industrial accounting is the most flexible and accommodating science known to mankind. Set half-a-dozen men to working independently on as many different sets of industrial cost records, and you will get just that number of different costs, and the correctness of each and every one is susceptible of proof by the unimpeachable rules of mathematics.

The total cost of electric power begins with the water on the hilltop, or the fuel in the earth, and ends only with the light emitted from the lamps and the power delivered from the shaft of the motor. A single individual or corporation rarely deals with the entire chain of operations, and the cost of the electric power, and the relative importance of the several items entering into the cost, depend largely on how many links in the chain are under consideration. For example, the author in speaking of the interest on the investment as a factor of the cost, says "It is frequently very large with water power, due to the hydraulic development required," etc. It might be added that it is sometimes very low, in cases where a hydraulic development company delivers water at the plant.

If we are to accept the author's inference that the cost of electric power stops at the terminals of the generator, and that the prime mover includes everything from the generator back to "nature's stores", then we must perforce agree with his statement that "In the cost of electric power the electric machine plays only a subordinate part; the essential element in determining the cost and the reliability of electric power is the prime mover."

There are some electric power enterprises that include expensive hydraulic development plants, or to speak more accurately, there are some large hydraulic development enterprises that include electric power plants as convenient transmitting mediums. I also know of one concern so happily situated as to be able to dispose of its output to a customer who furnished his own switchboard, transformers and transmission system. On the other hand, in how many instances does the owner or operator of an electric power plant get much nearer to "nature's stores" than the coal car on his railway siding, and in how many instances can he dispose of his output without delivering it on his customer's premises? Surely the instances are not so numerous as to warrant any such sweeping statement as that quoted.

I will not venture to intrude any discussion on the classification of electric power service into five different grades of quality. Your association may have under consideration the wisdom of setting up an official standard scale of badness. It might be useful to a manager of an electric power station as an instrument for convincing a complaining customer that he had no business to complain. To the manager whose plant is giving only mediocre service, it might be a comfort to know that he was still one or two degrees within the boundary of official recognition.

That part of the paper devoted to the thermodynamic consideration of heat motors, seems to be simply a brief resumé of several of the standard propositions that are demonstrated in most of the elementary text-books dealing with the subject. Those who have studied the mechanical theory of heat to the extent required in a modest technical course, will accept the statements put forth without argument. Those who have not a reasonable grounding in the subject must accept the statements as dogmatic.

We are introduced to a new unit of energy, which is referred to as the "kj." I am glad to be confirmed in my suspicion that this is a kilojoule, but it is a little difficult to see why it is used to the exclusion of the more conventional units that are commonly found in text-books on thermodynamics. As the value of a kilojoule differs from that of a British thermal unit by less than 6 per cent, we may accept it as a sort of "esperanto" term which conveys practically the same idea to those who think in metric measures and those who think in British measures. We also meet two old friends of the thermodynamic cycle family with new names. Isobaric and isovolumic would be convenient terms, were it not that the text-books recognize two other air engine cycles, those of the Ericsson and the Stirling engines, in which the isobaric and isovolumic features are respectively combined with isothermal expansion and compression instead of adiabatic. I wonder if I dare suggest as a solution of the difficulty, isobarabatic and isovolumbatic—words which if not more significant, are more sonorous.

Referring to the efficiency curves in Fig. 1, we naturally expect the curve for the Carnot cycle to stand at the top, as it is our standard of the highest efficiency attainable. We expect the cycles which are designated as isobaric and isovolumic to fall short of the efficiency of the Carnot cycle, because they do not receive all their heat at the highest temperature, or reject all of it at the lowest. We expect the isobaric and isovolumic cycles to be equal in efficiency, for the reason that while they deal with different total quantities of heat, the amounts received and rejected at corresponding temperatures are strictly proportional. We expect the curve for saturated steam to coincide with the curve for the Carnot cycle between the same temperature limits, for the reason that the ideal cycle for saturated steam is a Carnot cycle. The only reason the curves do not coincide in the figure is, that different minimum temperature limits have been selected. We expect a decided change in the steam-cycle curve, at the point where superheat begins, for the reason that we there depart from the Carnot cycle and begin to take in heat at varying temperatures.

At higher temperatures we expect this superheated-steam curve to fall below the isobaric and isovolumic curves, for the reason that a larger proportion of the total heat dealt with was received at lower temperatures.

The curves of relative output per unit weight do not uncover any surprises. It is the heat and not the substance, that does the work. As steam has a greater heat-carrying capacity than air, naturally the work done by the heat that can be put into a unit weight of steam will be proportionately greater than that done by the smaller quantity of heat that can be put into a unit weight of air, temperature limits being the same.

The output of the isobaric cycle, we expect to be greater than that of the isovolumic cycle, just in proportion as the specific heat of air at constant pressure is greater than the specific heat at constant volume, which corresponds with the ratio of the figures given in table II, column 1.

The expression $1 - \sqrt{\frac{T_2}{T_1}}$ for the efficiencies of the isobaric and isovolumic cycles is novel, but applies only to the special case in which the temperatures at the end of adiabatic expansion and compression are equal, which satisfies the condition for maximum output per unit weight of air as the working fluid.

In the Carnot cycle for air, it is quite reasonable that for a given lower limit of pressure and temperature there is for each upper pressure limit a corresponding temperature that gives the maximum output per unit weight of the working substance. If the temperature were increased to such an extent that it would require the expansion to be adiabatic over the entire pressure range, in order to reach the lower temperature limit, then there could be no isothermal expansion, no intake of heat and consequently no work.

It will be also noted that it is not alone with air as a working medium that the use of the Carnot cycle involves high pressures in order to utilize moderate temperatures. By a curious coincidence, the temperature given by Dr. Steinmetz as best for an air cycle with 24 atmospheres maximum pressure, corresponds almost exactly with the temperature of saturated steam of the same pressure. And this is why we use superheated steam. We cease to attempt to approach the Carnot cycle at the higher temperatures, and turn to a less efficient one in order to avoid inconveniently high pressures.

Superheat is not theoretically the most efficient means for utilizing great temperature differences, with steam as the working fluid, but for the present it is the most practical means available, and is much better than nothing at all.

Thermodynamics is a very interesting and almost limitless subject, but thermodynamics and practical commercial engineering overlap only to a moderate extent. The cycle of the heat motor is but a small link in the chain of processes involved in converting the energy of fuel into mechanical energy; and if one concentrates too much on this one link, he is apt to contract his field of vision.

The proper selection of a prime mover depends more than anything else on that valuable human faculty that we call " horse sense ",—which, like greatness, one may be born with, or may acquire, but which, unlike greatness, cannot be thrust upon him. It may be taken for granted that no manufacturer who has been prominently in business for ten or twenty years is putting out a distinctly bad heat motor.

The steam turbine may, for obvious reasons, without attaining prohibitive dimensions, be made large enough to efficiently utilize exceedingly low pressures and temperatures, when the low temperatures are available, but it does not follow that it must necessarily be so made. Because of the especial adaptability of the turbine for using large volumes of steam, and the excellent way in which the reciprocating engine handles steam at the small volumes consequent on high pressures, a high pressure reciprocating steam engine compounded with a low pressure steam turbine often presents a very attractive combination.

The mechanical difficulties involved in the attempt to utilize the full range of expansion of high-pressure steam in a single cylinder of a condensing engine, have long been recognized as being at least fully as important as the thermodynamic difficulties. We are not confronted alone by high mechanical stresses but by prohibitive clearances, unendurable leakage losses, and the impracticability of a valve gear for the very short cut-offs that would be necessary.

The pressures in gas engines,—say 25 to 30 atmospheres—have not been found unduly difficult to cope with. The heavy reciprocating masses smooth down the peaks of pressure so that in general the mechanical stresses are well within the limits of conservative engineering practice. Gas producers are now obtainable which may be operated with the same degree of efficiency, reliability and continuity as the best boiler plants.

It can scarcely be claimed that one type of prime mover demands a higher grade of attendance than another, or that there is any serious difference in reliability as between the several types. The skill required to obtain the best results from the turbine or the gas engine, as compared with that required for getting equally good results from reciprocating steam engines is different in kind, but not necessarily in degree. Skilled attendants for steam turbines and gas engines are more uncommon than for reciprocating steam engines, but that is because we have been training attendants for reciprocating engines for 150 years, and the school has been a very large one. We have been training gas engine and steam turbine attendants for perhaps less than 30 years, and our educational facilities have until recently, been exceedingly limited in extent. There are dozens of men who can detect symptoms of trouble in reciprocating engines, and who can correct troubles before they become serious, to every one man who can do the same for a gas engine or a steam turbine. Yet the skilled gas-engine or steam-turbine attendant might not be able to display much resource in an installation of reciprocating steam engines. When we see a particularly fine piece of work, do we compliment the workman, or his tools? When we hear of an especially good record of electric power station service, both as regards reliability and overall economy, shall we compliment the prime mover, or the manager? The final overall efficiency and reliability of the plant depends on the human factor as well as the mechanical factor. The variations possible in the latter—considering, of course, only reasonably modern and accepted types of equipment—are so small as to be over-shadowed in the variations of the former.

Always the two-thousand-year-old parable of the talents is recalled to us. The talents differed not in goodness, and yet they produced widely different results, according to the respective efficiencies of the men to whom they were entrusted. And the parable would have been more realistic, and more in keeping with what we often see in our daily contact with the great and growing electric power industry, if he who was entrusted with only a single talent had, by his energy and foresight, equalled or surpassed him that was entrusted with ten.

David B. Rushmore: Almost every engineer has to do with a prime mover in one form or another, and questions arise in that connection, whether the engineer is an operating engineer or connected with a manufacturing company, or whoever he may be. One of the questions to be considered is, what shall be called the output or the rated capacity of these machines? This question nearly always arises in a comparison between machines manufactured by different concerns, where the basis for the rating has not been definitely fixed.

In the steam engine, for example, which is one of the oldest forms, we have a fairly definite idea when we speak of so many horse power output for the engine. The turbine, which is not as old, has a variable overload capacity, or an overload capacity not always expressed in the normal rating of the machine, and so there is considerable lack of definiteness which is sometimes confusing.

The gas engine is peculiar in a certain way, in that the rated output of the gas engine is one with a very small overload capacity. In comparing estimates on certain installations, which I have recently looked over, the engineers did not bear this fact in mind, and in certain industrial establishments which are now in process of construction, an active discussion is taking place as to which is the more desirable form of prime mover to use, in order to generate electrical energy from the gases of blast furnaces. This is the particular point I desire to speak on, not to reach any conclusion, because there is no conclusion which can be had at present. The factors which are going to form this conclusion are those not to be had in a way which is positively acceptable.

A steam turbine may have a thermodynamic efficiency under the conditions of operation which will approximate 13 or 14 per cent. A gas engine under the conditions of operation may reach 24 or 25 per cent. The output in the case of the gas engine is approximately 100 per cent more than we will get in the other case, and naturally, as has been the fact, people have wished this output, but the lowest cost of electrical energy is not the real thing that the owners of this establishment are after. It is the lowest cost of their output, and the factors which should be introduced into the problem are depreciation, repairs, and interruptions to service. In making a final comparison we must have more or less of that information at hand. Reliability insurance, which Dr. Steinmetz speaks of, appears not exactly in the way in which he has presented it, but in the choice of machinery to be used. If we have engines which must be out of service frequently, if we have engines with very high charges for repairs, if we have engines on which the depreciation is very high, if we have an installation the cost of which is from 50 to 100 per cent greater in one case than in the other, a thermodynamic efficiency which is twice in one case what it is in the other, will not make up for the influence of the other factors.

Calvert Townley: I understand that our respected President and some of his advisors have inaugurated a movement at

Washington intended to preserve the water powers of the country for the general public. It is proposed that when water powers are developed there shall be a payment made to the government proportionate to the output of such powers. I take this opportunity, therefore, to say that I believe such a course in many cases will absolutely prevent the development of water powers, and, instead of benefiting the general public by swelling the government income, will retard the advance of any industries that might be assisted by cheap power.

I presume that the idea of a charge, is born of the thought that water powers are enormously profitable to the owner, and that he should not be allowed to monopolize our country's natural resources for private gain. It has been my experience in New England, gained both from operating some water powers and in examining the commercial feasibility of others with a view to possible development, that in competition with steam, the majority of power developments are so heavily handicapped by fixed charges and operating difficulties as to make their commercial development of doubtful interest.

There is a decided similarity between many of the conditions affecting water powers in the several New England states; for example, the rain fall, the run-off per square mile of drainage area, and the relations between maximum, minimum and average flow. We can be fairly sure, for example, that the maximum flow of any stream will be about two-and-one-half times its average flow, not considering spring freshets, and that the minimum flow will sometimes drop to the vanishing point. Let us examine then the fixed charges of a water power which it is proposed to develop for the sale of electric energy in competition with that produced by steam. Assume that this power can be developed to 80 per cent of the maximum flow of the stream at a cost of $100 per kilowatt capacity, including hydraulic works, electric machinery and transmission line. This is a low figure for many water powers, but is purposely so chosen for purposes of illustration. We cannot safely contract to deliver a peak load greater than the average flow of the stream. Therefore, if it costs $100.00 per kw. capacity to develop 80 per cent of the maximum flow, and which flow is two-and-one-half times the average flow, the development cost for the average flow will be $200.00 per kw. The load factor must next be considered. It is a fortunate company that can show a load factor as high as 50 per cent,—that is to say, where the average 24-hour load is as much as one-half the peak load or station capacity. This means, then, that for the average current sold, which is really the unit that has to carry the full fixed charge, the investment is not $200.00, but $400.00 per kw.

In time of low water, the company must still be prepared to carry its peak load, that is, a load equal to the average flow of the stream. Last year the minimum flow was not to exceed 25 per cent of the average, requiring, therefore, a relay of at least 75 per cent from some source other than the water power itself. If this source be a steam plant, and the cost of such plant be taken at $100.00 per kw. rated capacity, there must be added $75.00 per kw. to our investment on which to base fixed charges, making the total development cost for each annual kw. sold, $475.00, or at only five per cent interest, not including depreciation, an annual cost of $23.75 over and above all operating expenses.

By contrast, a steam plant costing to build $100.00 per kw., and having a capacity equal to the peak load and operated with the same load factor previously assumed (50 per cent) must provide for fixed charges on $200.00 only, or $10.00 per year, taking the same interest as before. This shows at once a handicap of $13.75 per year which the hydraulic plant must overcome by lower operating expenses, before the water power is on all fours with the steam development. Where the load factor is lower, or the cost of the hydraulic development is greater per kw. capacity, or where depreciation is to be provided for, or a larger steam relay necessary, any or all of which conditions are frequently met, the hydraulic plant labors under a still greater disadvantage.

It will readily be seen, I think, without pursuing this comparison further, that any arbitrary governmental tax or charge will lessen the attractiveness of water power investment, and will so seriously handicap the development of a great number of powers as to entirely destroy their commercial availability.

My excuse for speaking of these obvious facts, which are known to many of you, is that there seems to be an entire lack of knowledge on this question by a considerable portion of the general public, resulting in the danger that unfortunate laws may be enacted tending to seriously injure an industry in which many of us are interested. Therefore, if you, as engineers, will, as opportunity offers, take pains to see that the fundamentals are understood, you can have a material effect on forming proper and intelligent public opinion.

In the absence of the author on account of illness the paper was presented in abstract by Mr. Berg, who replied as follows:

Ernst J. Berg: In concluding the discussion I shall not try to defend Dr. Steinmetz's paper nor the premises used in his arriving at the thermodynamic efficiencies, especially since I feel that it will give him great pleasure to do so himself. I will, however, add that when reading his paper this afternoon I found it most instructive and valuable. No doubt I have seen these thermodynamic cycles described in text-books, but it is so many years ago that I have forgotten them, and I am sure that they were not given in the concrete form that Dr. Steinmetz has presented. I know that there are other members in the same situation, and to them as to me the paper has a charm of novelty and is very interesting.

Dr. Steinmetz says, if I am not mistaken, that the limits of pressure and temperature chosen by him in working out the thermodynamical cycles might be somewhat varied, but he also states that the conclusions will not be much affected by such variations as long as they are reasonable, and I believe him. A temperature limit of 800 degrees cent. seems as high as could well be used, since I believe this to be the temperature at which the cylinders begin to be dull red.

As to the pressure, it seems that 24 atmospheres or about 350 lb. is as high as is good for conservative engineering, therefore, I find nothing wrong about the assumption. The efficiencies are finally based upon cycles which give the maximum work for given cylinder dimensions which seems also very fair. When finally the tables showed that the efficiencies, mechanical as well as thermoydnamic, were consistent with known facts, I was satisfied there could not be any criticisms on these scores.

Professor Lucke said that there were no conclusions given in the paper. That is true. I do not think Dr. Steinmetz wanted to give any, I do not think he wanted to say that any given cycle or type of prime mover was best. He made a fair comparison between the various prime movers.

Charles P. Steinmetz (by letter): As far as I can understand, Professor Lucke's lengthy, but rather unintelligible discussion, it is a general denial; in short, he says: The assumptions of my paper are wrong, the methods of reasoning are wrong, and the conclusions are wrong; while the second speaker, Mr. Longwell, explains in great detail, that the assumptions of my paper, the methods of reasoning, and the conclusions are old and well-known, and their correctness demonstrated in every elementary text-book, so much so that they do not require being stated. As the statements of these two speakers thus contradict each other, I do not need to discuss them further, but merely desire to point out to Professor Lucke, that the study of typical thermodynamic cycles is not useless, because no heat engine exactly follows any of these cycles. In electrical engineering also, no existing transformer exactly agrees with the typical transformer diagram, nor any existing transmission line with the equations of transmission lines, and even Ohm's law is not rigidly obeyed by any industrial circuit, as secondary phenomena, such as temperature changes, always occur. Nevertheless, we use these laws and methods in design and calculation, and the history of electrical engineering has amply justified us. Phenomena of nature are always complex, and thus can never agree completely with any typical representation; but it is the province of the engineer, to find the closest theoretical representation of the actual facts, and then bridge over the gap by engineering judgment.

While Mr. Longwell desires the thermodynamic cycles omitted from my paper as obvious, for Professor Lucke I should have added an extensive discussion on the relations of the theoretical thermodynamic cycles to the actual cycles in heat engines. I have thus chosen the middle ground, illustrated the reasoning on the typical thermodynamic cycles, and left it to the intelligence of the reader to realize that the actual engine cycles are intermediate between, and combinations of, the typical cycles, hence covered by the results of the typical cycles.

Professor Lucke's statement, that the temperature range has no effect on the efficiency of the thermodynamic cycle, obviously is wrong. If his idea of gas engine design is to put as much heat into the cylinder as possible, and see what power he gets out of it, and he does not care to know what the temperature is, this obviously does not prove that the temperature is immaterial.

In general, an efficient designing engineer endeavors to know not only what is put into, and what comes out of an apparatus, but still more, what takes place in the apparatus. The rapid advance of electrical engineering is to a large extent due to the feature, that the designing electrical engineer was not satisfied merely to put as much mechanical power into the machine as possible, and measure whatever electrical output he got, but has carefully studied the internal reactions of the apparatus, and thereby been enabled intelligently to choose and predetermine the actions, with the result that the waste of power in electrical apparatus has been reduced to a negligible quantity.

However, Professor Lucke's method of gas-engine design, by putting as much heat as possible into the cylinder, is merely a repetition, in different words, of the assumption which I made in my paper for the air cycles. These cycles I consider for the conditions of maximum output, where the greatest amount of heat is put into the cylinder, which still increases the output.

The claim made by Professor Lucke and Mr. Longwell, that the assumptions made in my paper are arbitrary, and by a different set of equally justified assumptions any other conclusion can be reached, is wrong; the assumptions made in my paper are not arbitrary, but, as proper in such investigations, I have chosen the conditions most favorable for each case. That is, where the efficiency or output increases with the temperature, I have chosen the highest temperature; where the efficiency or output increases with the pressure, I have chosen the highest pressure permissible by reasonably conservative design. The only feasible variations of the assumptions thus are minor changes; some engineers may consider 24 atmospheres as too high, and prefer 20 atmospheres as a more conservative limit, while another engineer may be willing to allow pressures up to 30 atmospheres. As I have stated in my paper however, the results, and the conclusions, are not appreciably changed by any reasonable change of my assumptions.

Incidentally, Mr. Longwell is mistaken in his statement, that equality of the two intermediate temperatures of the air cycle fulfils the conditions of maximum output per unit weight of air. This happens to be the case for the two cycles specifically discussed in my paper, but not in general. For instance, for the air cycle of constant pressure admission and constant volume exhaust, in the conditions of maximum output—which is the assumption of my paper—the two intermediate temperatures are not equal. His statement, that the efficiency of the isobaric cycle of saturated steam is that of the Carnot air cycle between the same temperature limits, is not quite correct either, but the efficiency of the steam cycle is slightly lower, though the difference is usually small.

My paper discusses the economy of the production of electric power from nature's stores of energy to the switchboard. If one corporation develops the water power, another one uses it by buying the water of the former. This obviously does not change the cost of development etc., and you do not get water power without cost of development, as Mr. Longwell seems to think, if you let somebody else develop the water power, and pay him for the cost of development in the price of water bought of him. The economic considerations from the station switchboard to the light radiated from the customer's lamps, are equally important, as Mr. Longwell states, but they are not the subject of my paper.

I am sorry that Mr. Longwell thinks the kilojoule a new unit: the kilojoule, or kilowatt-second, is, and has been for some decades, the international unit of energy, used throughout the world, not only by the electrical engineers, but also by other engineers, chemists as Ostwald, and others, with the exception of that rapidly dwindling group of mechanical engineers in the two English speaking countries, who still prefer to measure distances by what in the earlier middle ages was considered the proper length of a king's foot, and to measure temperatures by a scale using as zero the lowest winter temperature of Northern Germany, and as 100 degrees an erroneous measurement of blood heat (Fahrenheit). While the two English speaking nations have not yet reached the courage of completely freeing themselves of the curse of the ancient " English system " (so-called because all the other civilized nations have long ago discarded it), with its seven or more incompatible units of length* and other curios, I would not impose such a system on the American Institute of Electrical Engineers which already years ago has gone on record as endorsing the metric system, by a ballot vote of over 90 per cent majority.

It is true, that in the English system, when expressing the energy of fuel in British thermal units, the output of the boilers in pounds of steam per hour, the indicated energy of the engine in foot pounds, and the output at the switchboard in kilojoules, the numerical values are not so disturbing to the self-satisfaction of the engineer as when throughout the entire transformation, the energy is expressed by the same units, and the inefficiency of the performance thereby shown in all its nakedness.

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* Foot, mile, chain, rod, fathom, knot, yard, etc.

But, whether such a hiding of the inefficiency is to the advantage of the art, is questionable.

In regard to Mr. Longwell's objections to my statements, that electric energy is a secondary form of energy, I shall be glad to withdraw this statement, as soon as Mr. Longwell will have succeeded in harnessing the thunder cloud, and light the cities from nature's stores of electricity, from lightning, or from the earth currents, or whatever other of nature's stores of electricity he has in mind for industrial use.

Before closing, I desire to correct a real error in my paper; in the diagrams, Fig. 4 and 5, the vertical line of cut-off before complete expansion, shown in the lower diagram, should in the abbreviated upper diagram be represented by a backwards curve, the reverse of the lower part of the adiabatic compression curve, and not by a vertical line, as shown in the figures.

DISCUSSION ON "THE INDUSTRIAL APPLICATION OF THE ELECTRIC MOTOR," NEW YORK, MARCH 12, 1909.

(Subject to final revision for the Transactions.)

B. A. Behrend: The subject of Mr. Shover's paper is not altogether confined to its title. Not only has he referred to the application of the electric motor in steel mills, but he has also described the usefulness of the storage battery in connection with steel mill problems. The application of blast furnace gas in the power plant at Gary has also been mentioned. It is carried out here on the most gigantic scale. As the paper itself does not rigidly conform to its title, I wish to make a few remarks concerning the gas-engine generating plant which is illustrated in Figs. 3 and 4.

As the designer of the 17 generators constituting the 40,000 kw. gas-engine power plant at Gary, I have been particularly interested in the paper, and I wish to take this opportunity to add a few words regarding some special problems which arose in connection with the generating plant, which will contribute to a better understanding of the fundamental conditions which must be met in power plants utilizing alternating-current generators for direct connection to gas engines, a problem of the greatest importance in steel mills. The choice of the right flywheel effect is intimately bound up with this question, as the necessary moment of inertia of the flywheel can be determined intelligently only by the designer of the alternating-current generators.

The gas-engine power plant at Gary consists of 17 four-cycle double-acting cross-tandem gas-engine units of 2500 kw. capacity each. Two of these engines, viz.:—1 and 2, are direct-connected to two 2000 kw., 250-volt, direct-current generators, while the remaining 15 engines are direct-connected to alternating-current generators of 3000 kilovolt-amperes each at 6600 volts and 25 cycles. The engine speed is 83⅓ rev. per min.

As the load on this power plant is composed chiefly of induction motors of large capacity and slow speed, the amount of lagging current under average operating conditions is likely to be equal to, or even greater than, the amount of watt current required by the motors. The power factor in this plant is not likely to exceed 70 per cent, and the generators, therefore, were designed for a large ampere rating at low power factor.

Electric gas-engine driven units must operate successfully in parallel if the gas engine is to be an important factor in steel mills. This problem resolves itself into an investigation of the periodic disturbing forces, produced by the engine, and the natural frequency of the generating unit. The periods of the former depend upon the type of engine used, if we neglect the period of the governor. As the gas engines at Gary are four-cycle double-acting, cross-tandem engines, there are introduced two periodic disturbing forces, due to inequalities in the force of explosions, adjustment of valve gear, leakages, etc., whose frequencies are one per revolution, and one-half per revolution, of the engine. It is the latter frequency which is absent in steam engines, and which introduces a complex factor of the greatest importance into the problem of parallel operation of gas engines.

Following the terminology used in dynamics, we call the results of these periodic disturbing forces, " forced oscillations." For the Gary units the frequencies of the forced oscillations, which are likely to be dangerous, are 1.39 and .695 cycles per second.

It was shown by André Blondel and Boucherot in 1893, that synchronous generators and motors, when displaced from a condition of equilibrium, perform a series of swings which constitute the " natural frequency " of the oscillation of the generator or motor, and which can be dampened out just like other natural oscillations. The damping circuits in and between the pole faces, which were suggested at the time by Maurice Leblanc, perform this function.

The determination of the natural frequency by calculation, as carried out by Blondel, Boucherot, and Kapp, ten years ago, was based on a knowledge of the angular displacement of the revolving field per unit torque. The short-circuit current was used for this determination, but experimental investigations which I carried out with my former assistant, Mr. A. B. Field, have demonstrated that other methods must be resorted to if serious error is to be avoided.

Supposing that we know the natural frequency of the generating units when operating on bus-bars of constant frequency, then we can readily obtain, by the methods of dynamics, the increase in the mechanical displacement produced by resonance, between the forced and the natural frequencies, or the " magnifying factor ", as it has been called by Messrs. Goerges and Rosenberg who have done such excellent work in the theory of parallel operation. This " magnifying factor " is infinite when the natural frequency equals the forced frequency, provided there is no damping. Under this condition, even with damping, however powerful, it is not possible in practice to obtain satisfactory parallel operation.

Turning now our attention to the Gary units, it was evident that if any measure of success was to accompany the construction of this plant, great forethought had to be exercised lest the successful parallel operation should be dependent upon a lucky guess on the part of the gas-engine builders. Before, therefore, calculating the moment of inertia of the units, or the flywheel effect, extensive experiments were carried on to determine the natural frequency of oscillation of generators of similar design. The generators were run in multiple when the circuit-breaker was opened and closed again immediately. The number of complete oscillations per second could be counted and the natural frequency was thus actually measured.

These investigations, carried on with a number of different machines, over the entire range of the saturation, made it possible to determine beforehand the natural frequencies at all excitations of the Gary generators, and, therefore, under all conditions of load and power factor. The curve in Fig. 1, marked " natural frequency ", shows the average result. The straight lines show the two forced frequencies of the gas engines. The points of intersection, *C* and *D*, mark conditions of instability, the range between them marking the range of stability. The operating range of the generators on the saturation and regulation curves, lies between *A* and *B*; and, therefore, is well within the range of stability.

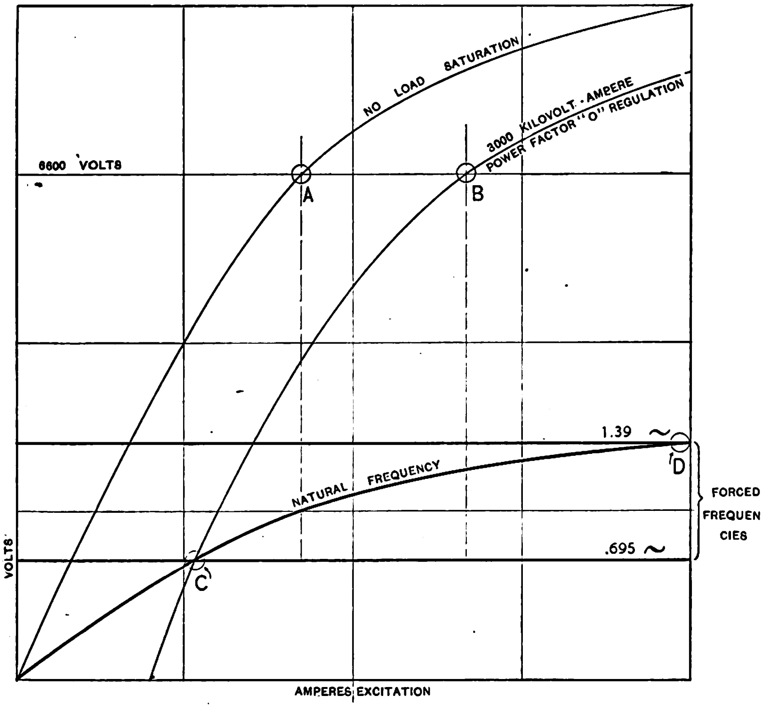


FIG. 1

Very light wheels had to be used to comply with the condition described. With light wheels, dampers are efficient and they have been provided on the Gary generators.

A flywheel effect, of four times the flywheel effect used, would have reduced the natural frequency below that of the lowest forced frequency, and the conditions would thus have been similar to those obtaining in steam engines. Such large flywheel effects on gas engines require the use of steel wheels of large diameter, which are not at all impracticable. In point of fact, the question was carefully considered whether large wheels, reducing the natural frequency should not be installed. It was, however, finally decided to bear up with the greater fluctuations, and to install light wheels working between the two forced frequencies.

These brief remarks may suffice to indicate that the problem of multiple operation of gas engines has been reduced to accurate scientific method based on careful experimental and practical data. While the details of the method, and the experimental data obtained, are beyond the scope of my present remarks, it should be mentioned that these methods have been applied to the plants of the Carnegie Steel Company at Rankin, Pa., where three 2000-kw. units are operating in multiple; to the plant of the Illinois Steel Company at South Chicago, where four 2000-kw. units are operating in multiple, and to the plant of the American Steel and Wire Company at Cleveland, Ohio, where four 1200-kw. generators are operating in multiple, and in all cases reasonably satisfactory parallel operation has been obtained. These plants are using blast furnace gas and the generators are of my design. In another plant, generators of my design direct-connected to gas engines are operating on producer gas, using flywheel effects large enough to reduce the natural frequency below the lowest forced frequency.

Gano Dunn: My admiration for the work done at Gary is not second to that of anyone here. I feel without the slightest exaggeration we are really considering one of the wonders of the world. I am reminded that the whole character of the Gary design is determined by the choice of prime movers, and that when we put our finger upon the quarter-of-a-mile of gas engines we have placed it upon the heart of the plant. I also feel that as Mr. Edison once expressed it, we are playing with blue chips, or as Mr. Carnegie once said, we have put all our eggs into one basket and are watching that basket. I believe so much attention has been put upon the gas-engine feature of the Gary plant that it simply cannot fail, and that the same intelligent engineering judgment that it is evident has been applied to other features of the plant, will be found to have been applied to the gas-engine equipment, and in the end although possibly after some trouble, we shall have a wonderfully successful plant that will set a pace to be followed all over the country, and that gas will be used for the fundamental equipment of steel mills.

In the early days when direct-current motors were applied to steel mills, their duty was regarded as intermittent. Their continuous capacity then was low, but their intermittent capacity was extremely high. So great has been the progress in the evolution of steel mills, that this type of motor, originally designed for very intermittent service, has come to be the modern mill motor, subjected to a service that is more severe than continuous service, a service in which through rapid reversal and the encountering of enormous inertias, the duty on the motor is even greater than that corresponding to constant continuous load. Of course the adoption of very large units for roll driving meant alternating-current motors. Had direct-current motors been desirable for the great rolls they could not have been used, because the sizes are beyond the limits of direct-current design. The general judgment of everybody is, that the adoption of alternating current in the Gary plant for the major part of the distribution, has been a success. The battle may wage a little about the choice of current for auxiliaries and small distributions, and in this connection I am particularly interested in what Mr. Shover said of the desirability of an induction mill motor. He wanted an induction mill motor that would be as much better than the ordinary induction motor as the direct-current mill motor was better than the ordinary direct-current motor.

If he wants this earnestly enough I have no doubt he will get it. The same intelligent coöperation between the manufacturing companies and the consumer, shown at Gary in the production of the great induction motors for driving the rolls, undoubtedly will be shown again in the production of a good induction mill motor, but I question if in the long run Mr. Shover will want such a motor earnestly enough. An induction mill motor that is as much better than the ordinary induction motor as the direct-current mill motor is better than the ordinary direct-current motor, is still not as good as the direct-current motor. I am reminded of the remark innocently made by Dr. Steinmetz on this platform not so very long ago, that if you reduced the frequency of a single-phase alternating-current motor, the characteristics of the motor improved, and were best when you reduced the frequency to zero; that is, used direct current.

It is the advantages of generation and distribution that have brought the induction mill motor to the front, not good qualities in the motor itself. The low power factors, the necessarily small air-gaps, the complexity attending the use of three phases with at least two sets of controlling apparatus, the great reduction in capacity for a given weight of motor; all in the end are bound to indicate that the problems of distribution ought not to be controlling to too great an extent, and ought not to cause the locating at every point around the mill where power is used, of the complications that attend an induction motor, but should rather lead to the collecting of such complications into a substation or power house where a motor generator taking power from the main alternating distributing system will transform it into simple and powerful direct current to be sent out for local service.

It is my opinion that in the end our steel mills will not be supplied throughout with alternating current but will find themselves equipped with mixed systems of distribution—alternating for the great powers and big motors, and direct for the cranes, reversing motors and other motors of similar service.

When the mill men first started electrical equipment, they were not in touch with the electrical men, and many mistakes were made. They were accustomed to steam engines and the measurement of power by indicators. On account of the difficulty of doing it, no one thought of measuring the power absorbed in accelerating. When motors were first used, accelerations were not yet vital items, and many of the mistakes and failures of electric motors in steel mills have been due to the neglecting of the vast amount of power absorbed by the inertia of moving masses. The railroad men went through all this and developed speed time curves. It was what Mr. Sprague, whom we heard last night at the annual dinner so correctly referred to as the "hero of Richmond", did not know when he put two 7.5 h.p. motors on a trolley car to do the work of two horses. Some of the most beautiful features of the Gary equipment are due to the appreciation on the part of the engineers, of the characteristics of acceleration loads.

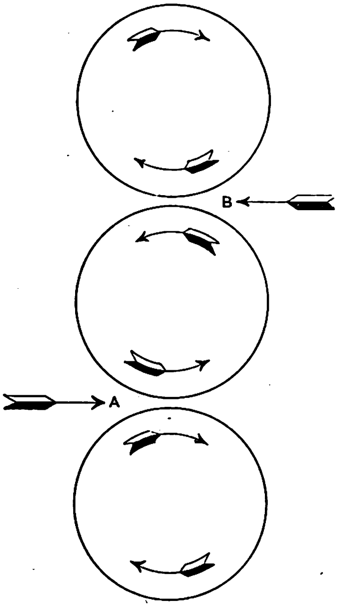
When I see how completely the steel industry has capitulated to the electrical engineer in the Gary plant I am filled with joy, remembering the attitude of the steel men toward electric motors not long ago, even on such innocent things as roll tables. Successfully to drive a roll table by motors was impossible. As for motors on the rolls themselves, you could not get a power station big enough to supply the current even if you could make the proper motor, which was doubtful. From such an attitude there has been victory after victory, until to-day we see one of the wonders of the earth completely electrically equipped. If the steel industry has capitulated to the electrical engineer, it is also true that the electrical industry has been developed by the requirements of the steel men, and has received the biggest kind of dividends from this development. It used to be said that electric railroad duty was the severest known to electric motors. It does not begin to approach in severity steel mill duty, and the modern mill motor, together with the great induction motors driving the rolls at Gary indicate how the electrical engineer has responded to the steel mill demands.

It is a great night, gentlemen. It means much for the future, and we shall look back to this time, signalized by Mr. Shover's paper as commemorating the solution of one of the greatest problems that electrical engineers have solved.

William T. Dean: Mr. Shover spoke very briefly on some of the problems which have been met, that is whether the mill shall be two high or three high. A three high mill is one having three rolls, each of which rotates constantly in one direction, that is, the upper and lower roll rotate in the same direction, while the middle roll rotates in the opposite direction, as indicated in Fig. 1.

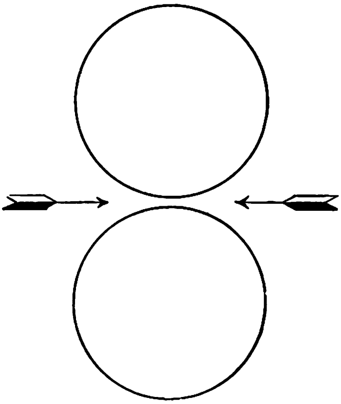
A piece of steel, for instance, passes through the lower set of rolls at *A* to the right, the table is then raised and it passes through the upper set at *B* to the left. On the two-high mill where the steel must pass back and forth through the rolls, as indicated in Fig. 2, it is obviously necessary to reverse the direction of the rolls, and therein comes the difficult problem in electrical drive, especially when large motors are used. The mill must reverse quickly to prevent delay, and in this, very serious problems are encountered.

Mr. Dunn mentioned the use of direct-current motors on the rolls which, in some instances, may be as large as 6000 h.p. Such a motor would be extremely difficult to design, but if it could be designed it would be a very expensive machine. A plan worked out in Europe, where direct-current motors of large sizes are used on reversing rolls, is to put three armatures on a common shaft, thus reducing the inertia on account of the diameters being smaller than if only one armature of large diameter were used.



THREE HIGH ROLL

FIG. 1



TWO HIGH ROLL

FIG. 2

Fig. 3 represents three direct-current motors, the armatures of which are mounted on a common shaft. As the mill reverses, it is impossible to take advantage of the mechanical value of flywheels; the enormous peak loads on reversal, therefore, are reflected back in the direct-current system, and to overcome this difficulty the three direct-current motors are electrically connected with two or three generators which are driven by an induction motor with a heavy flywheel, the generator armatures, motor armature and flywheel being on a common shaft, as shown in Fig. 4.

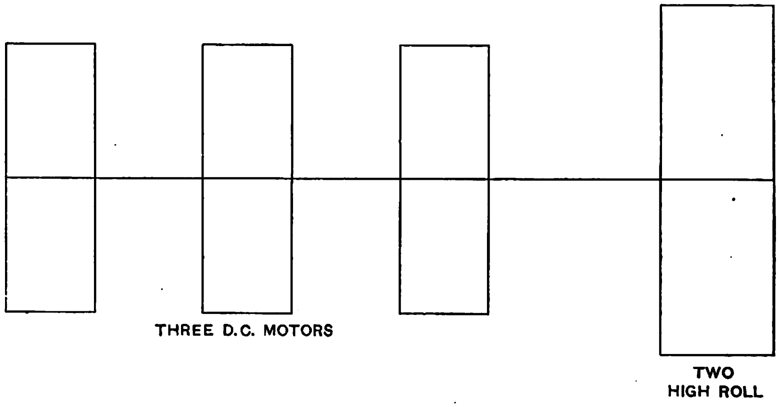

THREE D.C. MOTORS
TWO HIGH ROLL

FIG. 3

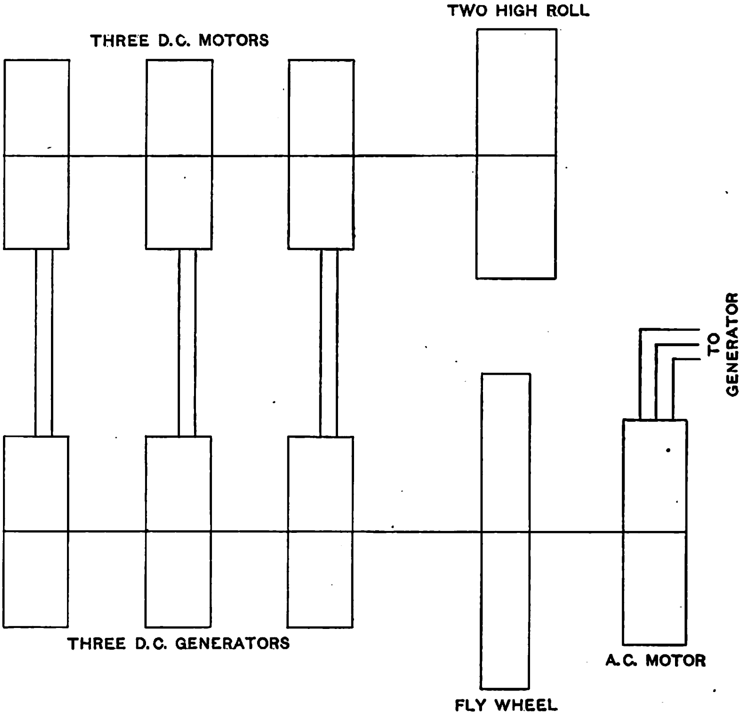

TWO HIGH ROLL
THREE D.C. MOTORS
TO GENERATOR
THREE D.C. GENERATORS
A.C. MOTOR
FLY WHEEL

FIG. 4

If now it were possible to use a three-high mill instead of the two-high mill, the system becomes considerably simplified, inasmuch as the direct-current motors and generators can be omitted, and the induction motor can be directly connected to the rolls, as indicated in Fig. 5. The induction motor with its flywheel will do the work on any equipment, and the difference in first cost is just about one to three.

This is one of the problems which I think has been solved, in connection with the study of the Gary plant, it being first proposed to install a two-high mill, but after careful study it was found that the three-high mill could be used at about one-third the cost of the two-high equipment and with a large elimination of troublesome features.

It may not be apparent why a mill should have ever been made two high. The steel business has been a gradual growth, the first steel being run through rolls driven by steam engines. The very first plan was to use small engines which were reversed at each pass, this practice having gradually grown to the larger work. Some of the older steel men do not believe, for instance, that universal plates can be made in any other than a two-high reversing mill, but some plants have demonstrated that they can be made in three-high mills, and by so doing, have greatly reduced the problems of electrical drive.

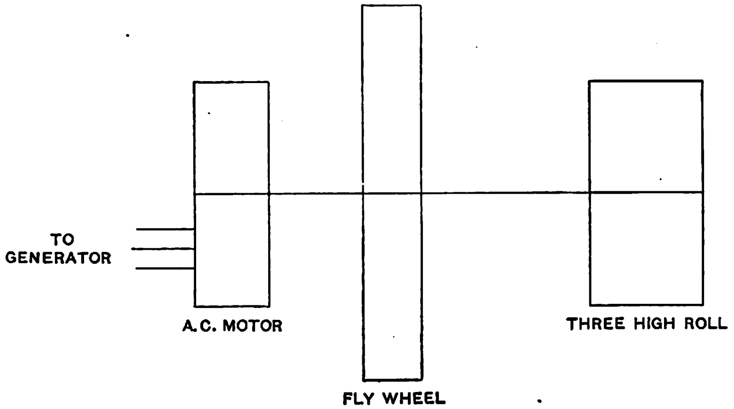


Fig. 5

On the subject of small alternating-current motors versus direct-current motors for driving auxiliary machinery in steel plants, I will refer to Fig. 6 which represents a small direct-current motor driving a roll table. In a system such as is used at Gary, this direct-current motor receives its power through a motor-generator set, the generator being driven by an alternating-current motor, which in turn receives its power from the alternating-current generators in the power station. If now an alternating-current motor were used on the roll table instead of the direct-current motor, the motor-generator set could be omitted by connecting the alternating-current motor direct to the power station through transformers if such are necessary. After all, simplicity of general construction as well as a general cheapening in the cost of the construction, are highly important features.

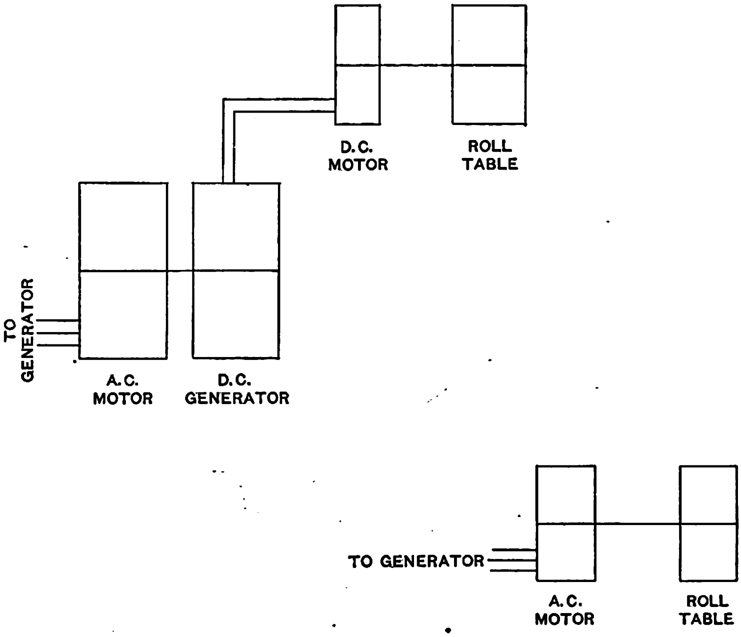


Fig. 6

Brent Wiley: Regarding the question of surplus gas power over and above that required by the furnace auxiliaries, a review of data obtained from several of the principal blast furnace plants abroad shows that the capacity installed per 100 tons of pig iron produced in 24 hours does not exceed 1500 h.p. The average pressure is approximately 8 lb. and the amount of coke burned per ton of iron produced is approximately 2400 lb. The author gives a surplus of 3000 h.p. per 100 ton of pig iron produced per day. I would like to have his opinion of a practical figure to use in this relation for comparatively small plants of more than two, and less than six furnaces of modern type and capacity. My idea would be an average of the two values given above, that is, 2000 h.p.

Referring to the subjects of ore unloader and ore bridge, I wish to submit data on power requirements of machines similar to those described, and which are located at the Lorain works of the National Tube Company. Two of the unloaders have a total of 475 h.p.—two machines a total of 525 h.p. and are of 10-ton capacity and the bridge has a total of 560 h.p., its capacity being 12 tons.

1 Unloader, maximum current 1200 amperes. Average current 500 amperes.
2 Unloader and 1 ore bridge, maximum current 3300 amperes. Average current 1520 amperes.
4 Unloader and 1 ore bridge, maximum current 6000 amperes. Average current 3500 amperes.
The voltage is 220.

With the older methods of unloading ore, where hand labor is employed to fill the conveying buckets, the unloading price per ton ranges from 12 to 18 cents, and for the boats of modern design ranging from 8000 to 1200 tons burden it would require several days' docking. Machines of the above mentioned type have reduced both the handling price and the holding time of the ore boats at the dock fully 75 per cent. This is a good illustration of the advance that has been made with the development of the auxiliary steel mill machinery; and motor application has been one of the prime features.

The principal point of the universal application of electric power in the steel industry is the commercial value, and this is made up of a number of items, some of which relate to the subject only indirectly. A summation of the advantages of the electric drive will bring out the questions that should be considered.

Advantages of electric drive.

1. More reliable, less breakage of couplings, pinions, etc., with a correspondingly less maintenance cost.
2. Low power cost, with the following advantages:
   Centralizing of power equipment, low fuel cost, use of gas engines of medium size in power stations, uniform load conditions in power station engines by equalizing methods.
3. Less space on account of absence of boilers, pipes, etc.
4. Easy adaptation to mill machinery.
5. Easy distribution by means of cables, instead of steam or gas pipes.
6. Easy and simple handling with reliable protective features of control.
7. Less labor.
8. Less oil and other stores.
9. Ease of obtaining power indications and records.
10. Constant and regular torque.
11. Increased output due to higher and more uniform speeds.

Referring to item No. 9—economical conditions can be worked out and modifications made with a knowledge of results based on exact information, having available power indications and records which do not exist with the use of steam engines. Again, power indications are of valuable assistance in locating faults of machinery, a timely discovery of which prevents loss of time and material, and probably damage to mill. The disadvantages mentioned by some engineers are high capital outlay, and loss of efficiency due to two intermediate machines between source of power and point of application.

Taking all of the above items into consideration, however, the results are decidedly favorable to the electric drive, especially for new plants; and it will be found that there are comparatively few cases of existing plants, where the conversion from steam to electric drive is not worthy of the fullest investigation. This point is emphasized by the very active interest taken in the exhaust steam-turbine proposition by a majority of the large steel companies. The exhaust steam from the existing mill steam engines is used to drive a low-pressure turbine connected to a generator which in turn furnishes electric power for the mill motors. Within the past two years the steel companies of the United States have installed more than 200,000 h.p. of gas engines and turbine electric station equipments, to drive approximately 15 motor units aggregating 20,000 h.p., exclusive of 13 units of the Indiana Steel Company now operating and on order and aggregating 51,700 h.p.

Within a year or so the data obtained from the above installations should give a conclusive analysis of the electric drive from both an actual and comparative cost standpoint, and while it is scarcely probable that this information will be available in detailed form, the electric companies are certainly justified in requesting that a review of the summary of the compiled data be made. It is to be hoped that attention will be given to the various phases of the question, bearing on such items as are mentioned under the heading " Advantages of the electric drive," in order that the full significance of the subject may be recognized.

The universal application of electric power at the Indiana steel plant, makes this subject of electricity versus steam a particularly fascinating one. In no other case has work of such magnitude or of such completeness been considered. Each mill proposition has been analyzed with great care and skill by the steel companies' engineers and they have outlined their conditions and requirements in a very definite and conclusive manner. The electric companies have appreciated this excellent work and as a valuable adjunct to his paper I would suggest that Mr. Shover add a copy of the specification, load diagram and data sheet items as furnished to the various electric companies for the rail mill proposition. This may appear to be an unusual suggestion, but a clear conception of this method of presenting a rolling mill proposition would further the development of the art to a greater degree of perfection, and this particular point is one of mutual interest and benefit to the steel and electric interests.

Robert Hull: The gas engine will have more and more to do in the manufacture of steel. An important question in the case of gas engines operating alternators is that of hunting, and I would like to have Mr. Shover give us his experience on any trouble with hunting he has had, and also some information as to the power factor.

David B. Rushmore: It is my pleasure to-night to call attention to the fact that this is the beginning of a new era in the work of the Institute, and one which will be very closely associated with the administration of President Ferguson. It is interesting to note that for an illustration of the industrial application of the electric motor, it was necessary to go quite near to his own home. We have for years been familiar with the application of electricity in the telegraph, in the telephone, in lighting, in electric railway service, etc., but it has been only in machines of small sizes, and only in installations of comparatively small total capacity, that we have heard of the industrial use of the electric motor.

But we have in this installation, the beginning of a new era in electrical work, where the application of electricity to industrial power more than takes an equal footing with the earlier application in other fields. In mill work, especially in this plant, we have very unusual conditions.

Owing to the limited time it is desirable to confine my remarks to one phase of the subject. In this plant, with its many varied applications of electricity, two features stand out distinctly considering the scale on which they are practiced in the manufacture of steel in this country. I refer; first, to the gas-engine power station. While such stations have been installed in other places on a smaller scale, it is the first time in this country that the complete power plant of a steel mill has been electrically operated. Secondly, I wish to refer to the drive of the rolling mill by electric motors. Smaller installations have been put in before, but nothing of this size and nothing in the world has ever been attempted with machines of this capacity.

In rolling mills we have a number of varied problems, and it is very pertinent to repeat the remarks of the previous speaker to the extent that under no other conditions of service are the requirements of the electric motor as severe as they are in this work. The load curves we saw this evening on the auxiliary as well as on the main roll drive, indicate a load condition not met with elsewhere. This necessitates in the motor, a very unusually strong mechanical construction and an interesting mechanical device mentioned by the author; it necessitates a comparatively large air-gap in the large machines, and also in smaller machines, making the design of the machinery, electrically and otherwise, with the idea of reliability first.

The author has very interestingly brought out the point that what a steel mill desires is nothing but the maximum output of steel, and the incidental features of the design must all be kept with this in view. That means that the electric motors have a considerably larger air-gap than was necessary from any other consideration; that the factor of safety, electrical and mechanical, very much exceeds the figures that would be used for any other class of service, and as he saw, in regard to the overload capacity of these motors; no variation in temperature of ingots should be able at any time to stall them. This is illustrated in the new type, where all the mills operate continuously in the same operation, and all the motors are equipped with flywheels.

The design of a flywheel and the motor, with the automatic control, in order to have the motor properly function with its variation in speed, to draw the proper amount of energy from the flywheel and throw back on the power station the desired load has been one of the very interesting problems of this work. Other engineers connected with the steel corporation have been studying, and have worked out with a very considerable degree of refinement the load thrown on the rolling mill by the reduction of the steel passing through it. This has been done to a large extent by the indicating steam engine, and now with the beautiful accuracy possible with the electric motor, a much more refined study of this problem will be possible.

The question of the alternating-current motors is a very vital one, and I wish to speak of it in connection with another engineer who has done a large amount of pioneer work for the Illinois Steel Company, and who is going to be the pioneer in introducing through the system which he is operating, high-speed rotary condensers, which entirely take care of the power factor, and the effect of the peak on the generating station, and which will allow in this plant, and the other plants in which they will be used, all the advantages of the electric motor, with the power factor obtainable, with that of zero frequency, which we have just heard.

The President: Before I call on Mr. Shover to close the discussion, I want to say a word which I thought of mentioning before, but as the hour was so late I omitted it. This subject of industrial power, not only as applied to steel mills, but to all practice, is really very important. It is not quite so pyrotechnic, as some of the other things we have discussed, like the electrification of railways, for instance, but there is a great deal of work which is being done very quietly in the application of electricity for power purposes, but not nearly as much as should be done. It was with the idea of bringing out the possibilities of the use of electricity for power purposes generally that this year I appointed a commitee on industrial power, of which Mr. Rushmore is the Chairman. It was hoped at this meeting we would be able to have a discussion of more than one feature of the subject, but when we looked into the matter, we found the application of electricity to power purposes in steel mills was so important, and involved such large quantities with such a great variety of applications, that we felt it was worthy of a whole evening, and I think we all feel that opinion is justified by the results of listening to Mr. Shover's interesting paper and the discussion which has followed.

We have arranged that the annual convention, if possible, should devote a session to the general subject of industrial power. We will then have a symposium on the subject, and discuss industrial power in all its phases, and we hope you will all be very much interested. I desire, to let you know that this is only the beginning of what we think is a new and important work.

Mr. Shover: Mr. Hull's question raises a doubt. We have had some slight difficulties in paralleling the gas engines; the trouble, however, existing only at times of light load. The operation of the alternators, in parallel, under three-quarter load, or more, is in the main as steady as are any reciprocating steam engine driven alternators. On lighter loads there is always some inclination to hunting, due to the inherent characteristics of the gas engine, in that there is always one cylinder which is a little stronger than the other, that is one end of one cylinder, and always one cylinder which is a little bit weaker than the others. Therefore, when you come down to the light load, you may come to a point where this weak cylinder misses fire, in which case it will be noticed that the needle on your ammeter on the switchboard will show it. The strokes of the engine can be counted at that time. There is also the strong cylinder, and if there is a light cylinder and this heavy cylinder, going exactly opposite to each other, then we do have more or less trouble with the machine. I have never seen them throw out of step, even under the very worst conditions, but I thought they were going to. The reason why it seems almost impossible to overcome these inherent characteristics of the gas engine, I do not think it is necessary for us to take up here. The question of the power factor which was brought up, is one which was held up as a scarecrow for a long time, in fact our attention was called to that to such an extent, we ceased to shy at it any more. We did not know what our power factor was going to be in this plant; we had no way of finding out, and we finally came to the point where we did not care what it was. The only thing we could do was to put the plant in, operate it, determine the power factor, and then ascertain if correction was necessary. We have not yet reached the point where we can say what we are going to do, because the heavier the load on our plant the better the power conditions, and when we get the mill full of steel, we will know what it is going to be. At present, I will say that our power factor varies according to the conditions in the mill, from 35 to 85 per cent.

Adjourned.

DISCUSSION ON "CONDITIONS AFFECTING STABILITY IN ELECTRIC LIGHTING CIRCUITS." NEW YORK, JANUARY 8, 1909

(*Subject to final revision for the Transactions.*)

Chas. P. Steinmetz: The interesting phenomena of instability of electric circuits, discussed by Professor Thomson, have an importance far beyond the arc circuit: the arc circuit is the first and therefore the best known type of unstable circuit due to the work of Professor Thomson and other investigators; but instability occurs frequently also in other electrical and mechanical systems, and the study of the conditions leading to instability thus is one of the most important subjects of electrical engineering. Thus we find synchronous and induction motors drop out of step, or find such motors starting from rest, but failing to run up to their proper speed; we meet with surging of synchronous apparatus, and find electrical apparatus misbehaving, apparently without reason, at the end of very long transmission lines. In all these phenomena, the same characteristic is the cause of instability, which has been investigated so ably by Professor Thomson in the early days of the arc circuit. It is: if the effect of a cause is in opposition to the cause, the system is stable; if however the effect assists the cause, it becomes accumulative, and instability results. When dealing with energy, as corollary from the law of conservation of energy follows, that the effect always opposes the cause, and thereby limits itself. When not dealing with the question of energy however, the effect may assist the cause and thus give instability. The typical case hereof is that of an arc in a constant-potential circuit. The voltage consumed by the arc decreases with increase of current. The current depends on the resultant e.m.f., that is, the difference between impressed e.m.f. and between the voltage consumed by the arc. An increase of current causes a decrease of the arc voltage and thereby an increase of the resultant e.m.f., hence a further increase of current etc., that is, instability: either a short-circuit, or extinguishing of the arc. The cause of this phenomenon here is the volt-ampere characteristic of the arc, shown in Fig. 1, as *I*, which decreases with increase of current. Assuming now a metallic resistance r inserted in series with the arc. The voltage consumed by r is shown by the straight line *II* in Fig. 1, and the total voltage consumed by arc and series resistance is curve III. This curve III has a minimum point for a certain critical value of current i_0: above this value, the conditions are stable, that is, an increase of current requires an increase of voltage, and thereby limits itself; two values of current, i_1 and i_2 thus exist at the same supply voltage, of which the upper one, i_2, gives stability, while at the lower one, i_1, the arc is unstable, and either goes out, or the current increases, until the upper value of current i_2, and thereby stability, is reached.

Similar relations as between the arc volts and amperes, are frequently met in electrical engineering, for instance in the relation between speed and torque of the induction motor. The speed-torque curve of a polyphase induction motor is shown as D in Fig. 2, with the speed as abscissae, the torque as ordinates. Assuming such an induction motor operating on a load requiring a constant torque, as when driving a reciprocating pump working against a constant head of water. Then in the range between synchronism and the maximum torque point m, the speed of the motor is stable. Thus at the load L, the speed c

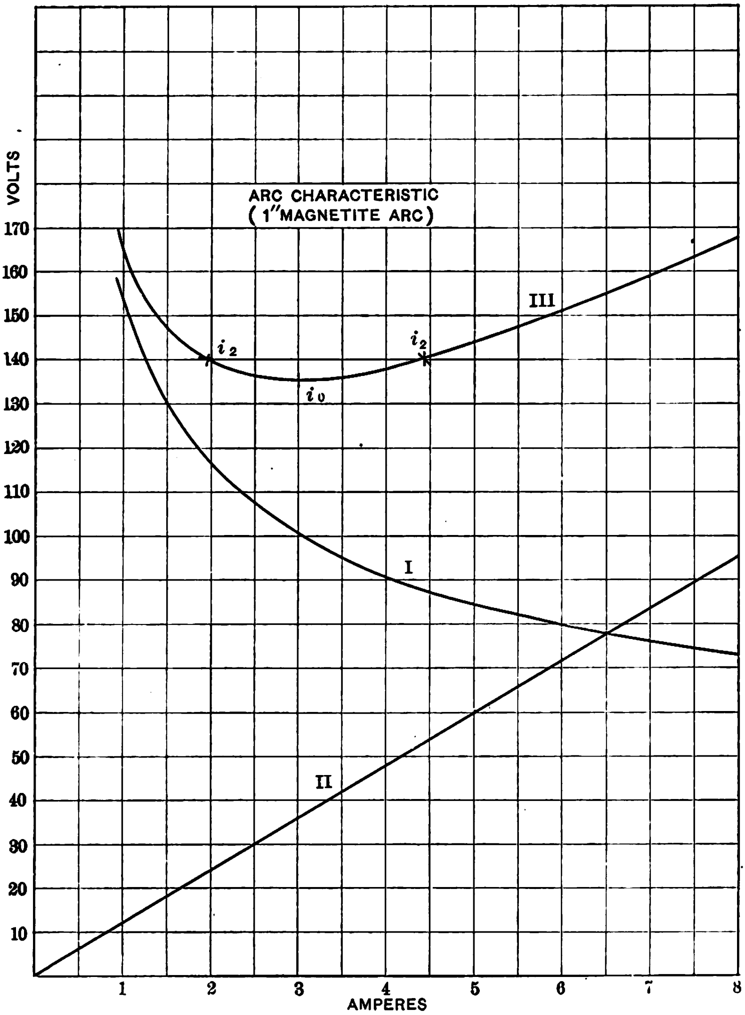


FIG. 1

is 94 per cent of synchronism, and any momentary increase of speed decreases the torque, a momentary decrease of speed increases the torque, and thereby limits itself. The same torque is reached again at a lower speed *d*, of 55% of synchronism. This speed, and the entire range from standstill *t* to the maximum torque point *m*, is unstable, that is, at the point *d*, the motor either drops down to standstill, or runs up to the stable speed *c*, but can not continue to revolve at *d*, on a load requiring constant torque *L*.

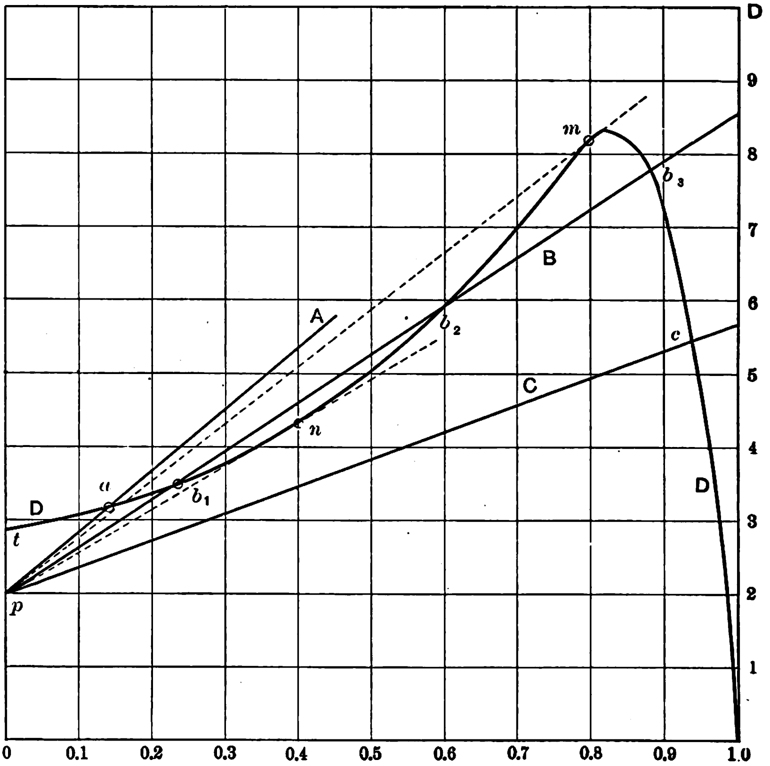


Fig. 2

The conditions of stability or instability of induction-motor speed, as discussed here, apply only to the case of a load requiring a constant torque, just as the stability consideration of the electric arc applies only to the case of constant voltage supply. The question of stability of electric and mechanical systems therefore involves two conditions: the circuit or system, and the external conditions under which it is stable or unstable. That is, in the present instance, the volt-ampere characteristic of the electric arc, and the condition of constant voltage supply;

or the speed-torque characteristic of the induction motor, and the condition of constant torque of the load.

Assuming for instance a load requiring a torque proportional to the square of the speed, as when driving a centrifugal pump, or a ship propeller. In this case, if the required starting torque *p* (Fig. 2) is less than the starting torque *t* of the motor, the motor always starts and runs up to the speed corresponding to the load: a high speed *c* for moderate loads *C*, a lower speed *b* for overloads *B*, and a low speed *a* for excessive loads *A*; but the speed-torque relation is always stable, that is, with this character of load the induction-motor-torque curve has no unstable branch.

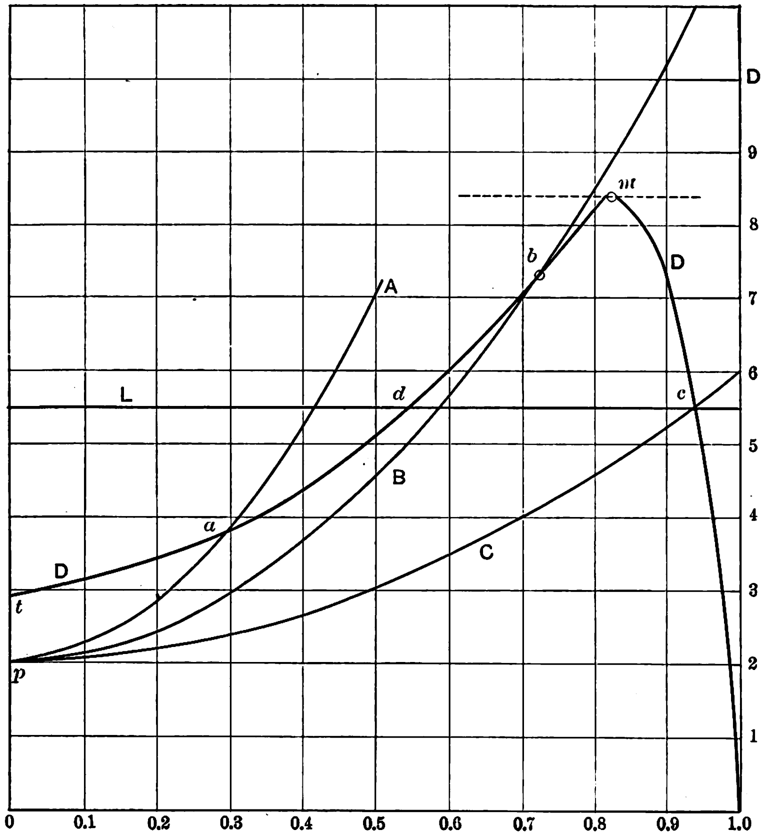


Fig. 3

Still more interesting are the speed-torque relations of the induction motor on a load requiring a torque proportional to the speed, as when driving an electric generator at constant field excitation and loaded by a constant resistance, as shown in Fig. 3. The motor always starts from rest. At moderate load the speed runs up to near synchronism, on straight line *C*. At excessive overloads, the motor still starts, but runs up to a low speed *a* only, and keeps revolving in stable condition at this low speed, that is, in a range of the motor curve, which on a load requiring constant torque is unstable. Especially interesting is the case of an intermediary load, represented by line *B* in Fig. 2. *B* intersects the motor curve *D* at three points, b_1, b_2, b_3, that is, three different speeds exist, at which the motor gives the torque required by this load, at 24 per cent, 62 per cent and 88 per cent of synchronism respectively. Of these, the intermediate speed b_2 is unstable, and so is the entire range of the motor curve between the points of contact *n* and *m* of the two tangents from *p* on curve *D*, while the low and the high speed are both stable. That is, if started from rest, on this load, the motor runs up to speed b_1 and stays there. If the load is taken off and the motor is allowed to accelerate near synchronism, and the load then put on again, the motor slows down to speed b_3 and stays there. At speed b_2 however, the motor can not continue to run, but either slows down to speed b_1, or speeds up to speed b_3.

We have here a case where a motor can carry the same load at two different speeds, a high speed, with moderate current: the proper running speed, and a low speed, with excessive current. In this case, the motor operates satisfactorily at speed, it always starts, but it does not run up to its proper speed, and shows a "dead point", or rather a "dead range" at intermediary speed. Phenomena of this character are frequently met with in single-phase induction motors, polyphase synchronous motors etc., though more or less complicated by secondary actions, as the effect of the motor-starting device, the magnetic locking of stator and rotor teeth, the induction machine action of the synchronous machine, etc.

Still a different form of instability occasionally occurs in induction motors on constant voltage supply and at a moderate drop of speed, frequently far below the maximum torque point, the motor suddenly drops out of step without previous warning. This phenomenon depends upon the relative momentum of the induction motor and its load, and of the generating system, and on the rapidity of voltage regulation of the generating system, and may become marked with a sluggish system of voltage regulation.

Of special interest also are different forms of instability, which lead to surging of synchronous machines, as the surging due to electro-mechanical resonance, which is frequently eliminated by lowering the motor excitation, that is, running with lagging current, while the surging due to the limited power supply of the generating system is intensified by lowering the motor field excitation, that is, running with lagging currents; and may disappear with over-excitation of the motor and operation with leading current. The study of these phenomena is of the highest importance, as apparently the same phenomena may be produced by entirely different conditions, and the remedy in one case thus may intensify the troubles in another case which resulted from different conditions. However, the subject is too vast to be dealt with in a short discussion, but may form a separate paper.

An interesting feature of the Brush arc machine is the great constancy of current independent of speed fluctuation: even speed variation of 50 per cent or over with such machines does not appreciably vary the current, but merely reduces the maximum voltage of the machine and thereby its output in proportion to the speed reduction. It is startling to observe in such a machine, at light load, when shutting it down, how perfectly constant the current remains even down to speeds of a very small percentage of normal speed, and until the very moment where the machine stops.

Another type of arc machine, a constant-alternating-current generator, deriving its constancy of current from armature self-induction, was once introduced into the industry, in the Stanley constant-current alternator, afterwards modified by the addition of a rectifying commutator into a constant-direct-current arc machine, but which disappeared after some years, apparently due to the unsatisfactory character of the arc lamps operated from it. It would therefore be of interest to hear something of this development of by-gone days.

Phenomena similar to the interesting case above discussed, of the induction motor, which can carry the same load at three different speeds, are occasionally met. Thus for instance there are conductors among the so-called " pyro-electrolytes ", which at the same constant-supply voltage can pass three different currents. The volt-ampere characteristic of one such conductor, a magnetite chromite alloy, is shown in Fig. 4. As seen in Fig. 4, at the same voltage, as 20 volts, the current can have three different values $i_1 = .45$; $i_2 = 5.0$; $i_3 = 36$ amperes.; and of these three values, the low one, i_1, and the high one, i_3, are stable, the middle one, i_2, and the entire range of the curve, between maximum m and minimum n, is unstable.

However, even the volt-ampere characteristic of the arc is not always the curve as shown in Fig. 1, but may be considerably modified.

This curve in Fig. 1 is fairly well represented by the equation:

$$(e - a)^2 \, i = \text{const.}$$

but applies only to the arc at constant vapor pressure, as the arc in air. A different volt-ampere characteristic results, if the vapor pressure in the space in which the arc is produced, varies with the current, as for instance is the case with a vacuum arc, as the mercury arc. Thus the volt-ampere characteristic of the mercury arc in stationary conditions, is of the character shown in Fig. 5, that is, has a range of minimum voltage at intermediate currents, while for smaller currents as well as for larger currents the voltage increases. Especially interesting is the latter range for larger currents, where an increase of current requires an increase of voltage. From our previous considerations, such a characteristic should give stability on constant potential supply, that is, for currents above the minimum voltage range, the mercury arc should be capable of operating steadily on constant-potential supply, without any series resistance, by any variation of current limiting itself. This however is not the case, but the mercury arc in a vacuum is unstable on constant potential over the entire range, just as any other arc, and for the same reason, that an increase of current causes a momentary decrease of voltage and thereby becomes accumulative. Thus, in the mercury arc of Fig. 5, an increase of current from 5 amperes to 7 amperes raises the voltage consumed by the arc from 33.2 to 36.6. In the first moment, however, after raising the current from 5 to 7 amperes, the voltage drops, as indicated in Fig. 5 in dotted lines, to about 30 volts, for a short time, a few seconds, but still long enough to be observed by the voltmeter, and then gradually, during some minutes, increases to its stationary value of volts. This leads to the distinction between the volt-ampere characteristic of the arc, shown in Fig. 5, and the momentary volt-ampere characteristic, and it is the latter which determines stability or instability. The latter is always dropping, and thus the arc is always unstable on constant potential.

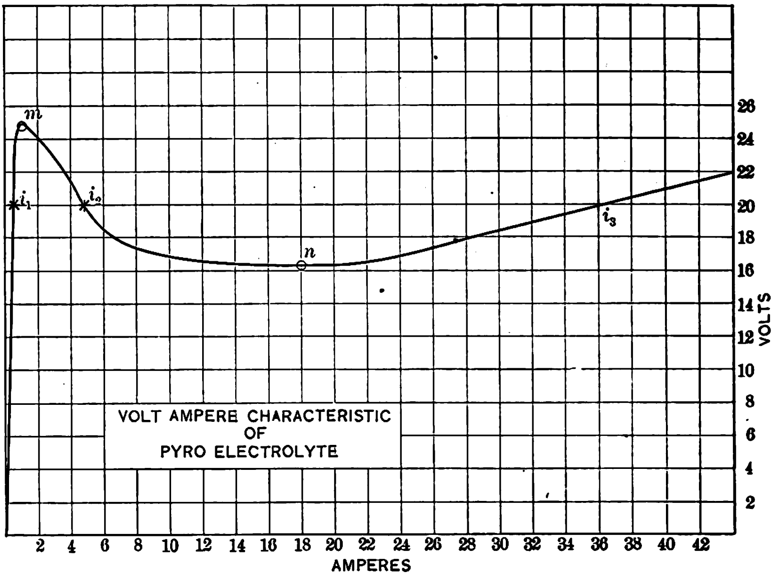


FIG. 4

In reality, the period of voltage drop with increase of current, is preceded by an extremely short period of voltage rise, that is, with an increase of current in the mercury arc, the voltage first rises, then drops, and then gradually rises to the final value, about as shown in Fig. 6. The first period, of high voltage, lasts for a thousandth of a second or less, but may be observed under favorable conditions by the oscillograph. It is the conduction through the vapor stream of previously existing lower current. With a velocity, possibly of some thousand feet-seconds, the conducting vapor stream of the arc adjusts itself to the change of current, hence drops in resistance and the arc voltage thus decreases approximately by above equation $(e-a)^2 i =$ constant. Gradually then the vapor pressure in the space rises, and the resistance of the arc stream thereby increases, and thus also the voltage. With an arc in enclosed space, the second period of low voltage thus lasts a few seconds only, while with arcs at constant pressure, as in air, it is the permanent condition, and the third period is never reached.

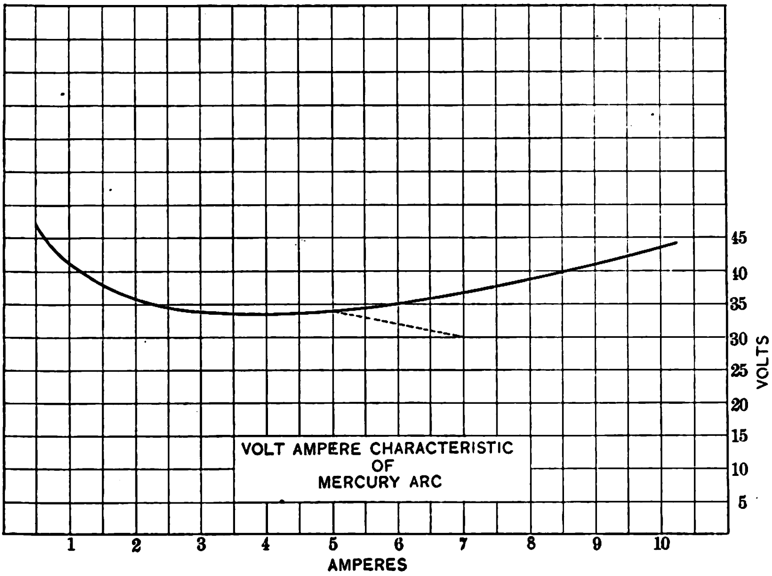


Fig. 5

The initial period of very short duration, where the arc conductor has not yet reached the stationary condition corresponding to the current flow, can be observed indirectly by superimposing on a direct-current arc a small high-frequency current and gradually increasing the frequency of the latter. Ultimately then a frequency is reached, where the power factor of the superimposed alternating current is unity, that is, the arc stream acts as ohmic resistance, or in other words, the variations of current are faster than they can be followed by the vapor stream of the arc. This transient period of the arc is of very great industrial importance. Extending the arc characteristic Fig. 1 back, it must intersect the zero line of current at the disruptive voltage, that is, the voltage required to jump a spark across the terminals. If then the arc is started by a spark, the volt-ampere characteristic traverses a curve starting with the disruptive voltage at the moment of the passage of the spark, and rapidly decreasing in voltage with increase of current. This transient

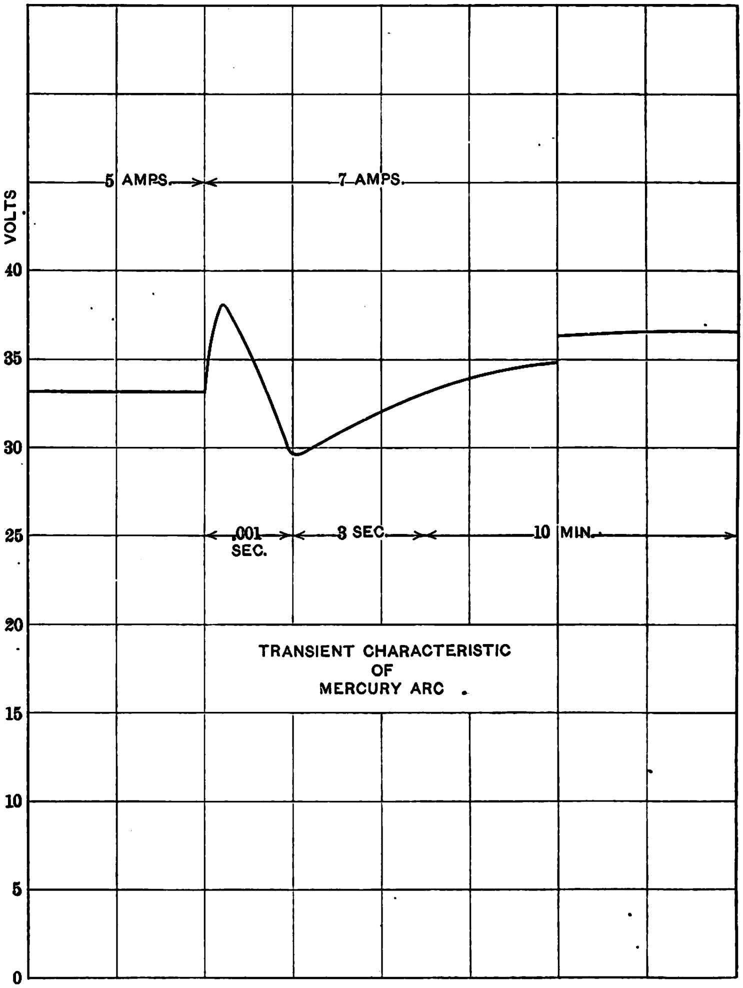


FIG. 6

volt-ampere characteristic however is not the curve in Fig. 1—which is reproduced as *I* in Fig. 7—but is higher; the more, the more rapidly the current increases, as shown by II and III in Fig. 7. In consequence thereof, if the high voltage lasts only a very short time, that is, decreases very rapidly, the voltage may fall below that required by the transient arc characteristic, and the arc goes out, or in other words, will not be established by the electrostatic spark, even if the voltage between the terminals is sufficiently high to maintain an arc when once established. This is the explanation of the phenomenon, that a static spark between terminals is not always followed by an arc, even if the voltage at the terminals is sufficiently high to maintain an arc when once established. Thus, while it requires about 100 volts

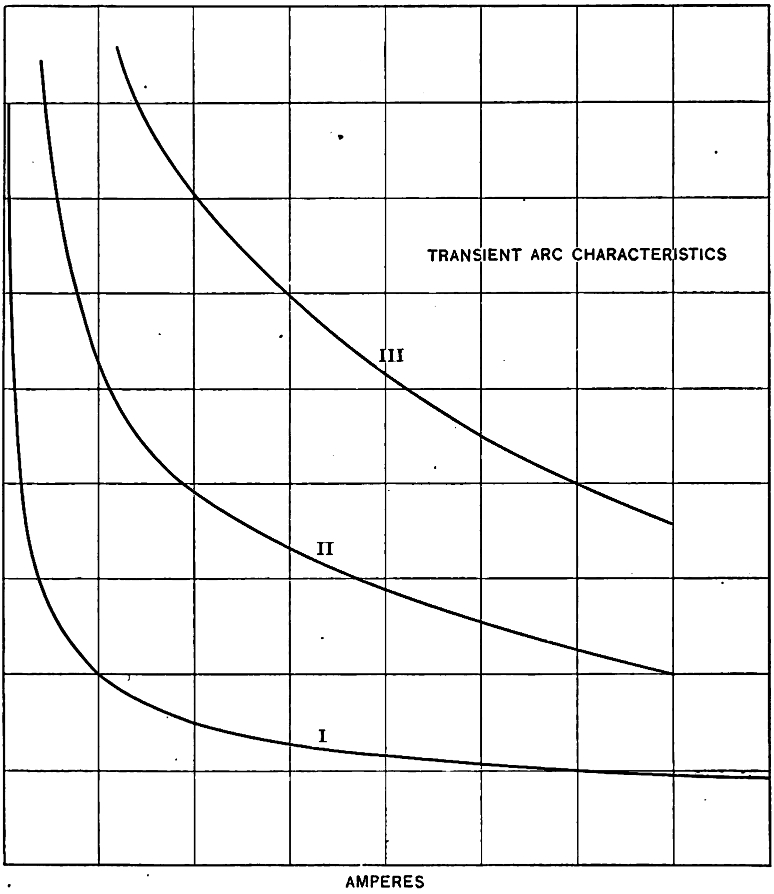


FIG. 7

to maintain an arc between terminals one inch apart, with 2000 volts potential difference between these terminals, static sparks may be jumped across these terminals, without any arc following: if the duration of the voltage which sends the spark across the terminals, is less than the time required for the transient arc characteristic in Fig. 7 to drop to 2000 volts. To start an arc disruptively, it therefore is not sufficient to have an electrostatic spark, but the spark voltage must be maintained sufficiently long to establish the arc, that is, supply the power required to produce the arc conductor at least so far that the maintained voltage between the terminals can hold the arc. How much power this is, depends on the permanent voltage between the terminals: the lower the permanent voltage, the greater must be the energy of a spark for starting an arc, and while a very powerful spark discharge may start an arc between terminals of moderate voltage, sparks of very high frequency and therefore very small power are incapable of starting an arc even at high voltage between the arc terminals. Thus, with such low power sparks, insulation does not break down instantly, but numerous successive sparks are required, before an arc follows. This is the reason why the effects of high voltages are so much more severe, if considerable power is back of the voltage, than are the powerless discharges of static machines.

This phenomenon of the time element required to establish the arc, is and has for many years been industrially used in the multigap lightning-arrester. This lightning-arrester consists of a series of spark-gaps between line and ground, over which high voltage discharges, but the arc can not be established during the short duration of the static discharge. It also explains the occasional failure of the earlier types of such lightning arresters, the number of spark-gaps being such that the machine voltage could maintain an arc across them, if the arc be once established, and the operation is based on not allowing the arc to be established. If however an exceptionally heavy discharge passes, the energy of the static discharge may be sufficient to establish the arc, and then the lightning-arrester burns up; for this reason this multigap type of lightning-arrester recently has been modified by adding various shunting resistances of different discharge capacity, so as to divert and destroy the stability of the arc.

In testing apparatus with high voltage, this phenomenon of low power static sparks must be carefully guarded against: because of the distributed capacity of the high-potential circuit, very high-frequency oscillations are produced, which, superimposed on the permanent alternating testing voltage, cause sparks to jump across the testing spark-gap long before the permanent voltage has reached the required values, and thus long before the specified insulation strain has been reached. In using a spark-gap in high-voltage testing, it is therefore necessary to insert resistances in series or in shunt to eliminate such oscillations, and a discharge of the spark-gap indicates the existence of the required test voltage, only if the spark is followed by an arc, but not otherwise. Thus I have seen sparks jump a one-inch gap, with the static voltmeter indicating only 10,000 to 12,000 volts, and by raising the voltage of the step-up transformer, the voltage indicated by the static voltmeter remained the same, but merely the frequency of the sparks increased, without however an arc following. As soon as an arc follows, the static voltmeter instantly drops to zero: short-circuit.

Elihu Thomson. It is gratifying that the paper served to get Dr. Steinmetz on his feet. We always learn a great deal from his discussions. May I suggest that it would be a capital idea for him to present a paper on other forms of instability. He has given half a promise that he would do this.

I agree with Dr. Steinmetz that it is a large subject and one can approach it from various sides. I have dealt with the most decided example of instability, the arc circuit, where all the conditions tend to instability, and effective provision has to be made to avoid instability. The other conditions Dr. Steinmetz has alluded to in the discussion are of course in similar lines, very suggestive indeed, and I think should be followed out. We should have a good exposition, such as I know he can give us, of the different forms of instability depending not only on the current, but instability of torque and speed, etc. There is, in fact, material here for several good papers.

Following Dr. Steinmetz we see the reason why it has been very difficult to work arcs of very small current value. They must exist if at all on the very steep part of the characteristic curve, and require high voltage, and potent influences to secure stablilty.

Dr. Steinmetz has pointed out the fact that there is an instantaneous effect before settling down, when a change is made in the current strength in an arc. He shows that this effect is in fact in an opposite direction to that which is the final result, and without doubt has indicated the true reason of the effect, in the time it takes for the shift in the volume of the arc stream or hot gases to take place. On an increase of current a slight excess energy must be absorbed while the arc is expanding, and this can only occur with a momentary increase of opposition measured as a resistance.

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THE PATENT SYSTEM IN ITS RELATION TO INDUSTRIAL DEVELOPMENT

BY FREDERICK P. FISH

In an address at Springfield, Illinois, delivered in February, 1860, Abraham Lincoln said:

> I have already intimated my opinion that in the world's history certain inventions and discoveries occurred of peculiar value, on account of their great efficiency in facilitating all other inventions and discoveries. Of these were the art of writing and of printing, the discovery of America, and the introduction of patent laws.

While other episodes in the history of the human race might well be added to the list, there can be no doubt that Lincoln was right in including the introduction of patent laws as an incident of prime importance. As he states later in his address—" The patent system . . . added the fuel of interest to the fire of genius in the discovery and production of new and useful things."

Progress has largely consisted in the recognition that things were wanted, and in the supply of them. Each success in meeting a want has led to an extension of the desires of man in a constantly widening circle. The inventors large and small have performed two functions. They have recognized the wants of the community in many cases before those wants were definitely apprehended, and they have supplied what was required or desired. They therefore stand in the front rank of those who have advanced the race.

It does not detract at all from the obligations which we owe the inventors, that they have dealt primarily with material, as distinguished from spiritual and intellectual progress. As a practical matter and in the long run, the latter are impossible without the former. Those who have advanced the industrial interests of man by increasing his control of the forces of nature, and teaching him how to apply those forces to shaping and transforming the raw materials which are available for our use, have supplied a necessary foundation not only for the physical needs of life, but also for that intellectual, moral, social and imaginative development which we all recognize as upon a higher plane than material well being.

Much may be said as to the evils arising from the complexities of modern life, and in favor of the simpler conditions of former times. It may reasonably be argued that the extraordinary material progress of the last few years has resulted in a development to some extent one sided. If such is the case, we need only to be patient, for the underlying forces of society will surely bring about the necessary readjustment of conditions when there has been time for the instinctive and automatic operation of those forces to correct the situation to the necessary extent. And the race will never lose the added comfort, the control of disease, the increase in the length of life, the startling economies in production and the wonderful facilities for intercommunication and transportation, bringing all parts of the world so closely together in thought and effort, which have resulted from our more recent inventions and discoveries.

There can be no doubt as to the validity of the view that has always prevailed, that material progress, although not in and of itself the highest goal to which we should aspire, is of underlying importance to our welfare.

It is no wonder, therefore, that the inventors and discoverers, who have enlarged the power of man to utilize for his own well being the forces and materials of nature, have been generally recognized as great benefactors. In Mr. Walker's standard book on patents, he quotes the following from one of the early works of Lord Bacon:

> Now among all the benefits that have been conferred upon mankind, I discover none so great as the discovery of new arts for the bettering of human life. For I saw that among the rude people of early times, inventors and discoverers were recognized as gods. It was seen that the works of founders of states, law givers, tyrant destroyers and heroes cover but narrow space and endure for but a time, while the work of the inventor, though of less pomp, is felt everywhere and lasts forever.

Not only was the work of inventors and discoverers in the old days rewarded by recognizing them as gods after they were dead, but it was appreciated during their lifetime, and was encouraged by the ordinary forms of compensation by which all services to individuals and to the community are recognized. Inventors and discoverers were rewarded by the respect and admiration of their contemporaries as well as by more material advantages. As was but natural, such rewards were in the first instance bestowed by the immediate beneficiaries out of gratitude for services rendered. The idea of definite stimulation to such service, which is at the basis of modern patent systems, did not become consciously recognized until a late period of history.

Not until the 15th century of our era do we find any attempt to reward an inventor by the grant of a limited monopoly of his invention, and even then it is doubtful whether there was in such grant any definite conception of encouragement for future effort, as distinguished from reward for value already received. Moreover, social and governmental conditions were such that it is not impossible that such grants were based upon favoritism as often as upon any principle of justice or sound policy. When we find what was the equivalent of a patent granted in 1467 for the manufacture and sale of paper in Berne; of another two years later in Venice for a privilege, exclusive for 5 years, of practising the trade of printing; another in 1507 in Venice of 20 years duration for the introduction of a process of mirror making, and a 10-year monopoly granted in France in 1551 for the same art, it is not at all clear that these isolated cases even foreshadowed our modern patent systems, in principle or in theory.

In England, however, toward the end of the 16th century, we find a rather definite recognition of the underlying basis of the patent system of to-day; but in so far as the sound, modern principle was apprehended at all, its conception was vague, and in its application it was confused with other ideas of governmental interest in, and control of industry, that were for a time, inconsistent with sound development.

The regulation and control of industries had been practised in England for many centuries. While charters had established artificial rules for the management of the different trades through the borough organizations, the guilds, and otherwise, at least as far back as the reign of Edward III what were in effect industrial patents, had also been granted for the purpose of inducing foreign workmen to introduce new arts into England. In this way, Flemish cloth makers, German armorers, Italian lass workers and French iron founders were persuaded to establish new industries in England with the hope of royal patronage. These new workmen established their industries side by side with those already existing and to some extent in competition with them. The entire system was one of regulation and control, and only to a remote degree foreshadowed the patent system that was to come. Most of the grants in these early days were to a large extent local in character. They were effective because England, almost alone among the civilized nations, had a government that was really national in its character, recognized and dominant throughout the land.

When the reign of Elizabeth began, the conditions were favorable for the adoption of a real patent system. That great Queen and her advisers were earnestly interested in the industrial welfare of the country. There was a fair degree of economic unity. The guild regulations were already declining. The field was open for development upon new lines.

The earliest recorded application for an exclusive patent of almost the modern type was in the year 1558. It was for the introduction of a new art into England and was presented jointly by an Englishman and an Italian. The petition was granted in 1562 as a " reward of diligent travail " and " to give encouragement to others," the precise grounds which justify the issue of patents under the patent systems of to-day.

At about the same time, another Italian presented a petition explaining that he had invented certain furnaces and " wheel machines " which others would copy without remunerating him unless he was protected. He prefaced his application with the suggestion that " nothing is more honest than that those who by searching have found out things useful to the public should have some fruits of their efforts and labors, as meanwhile they abandon all other modes of gain and are at much expense and inconvenience and often sustain much loss." This again is a statement which expresses the point of view and the experience of the inventors of the present time.

Prior to 1570 not less than twelve patents were granted in England for chemical products and processes and six for mechanical inventions. It is interesting to find these patents dealing with the familiar subject matter of salt, alum, saltpetre, oil, glass, cloth, dressed leather, and machines for dredging, draining and grinding. Soon afterwards there was issued a patent for sailcloth and one for playing-cards. From that time to the present, letters patent have been granted continuously in England as a reward to the inventor and an encouragement to others.

But the situation was not yet crystallized. The power to grant patents, where it was for the public interest that they should be granted, gave the opportunity to establish monopolies that were distinctly hostile to the public good. Elizabeth and her successor, James I, issued many such patents and licenses analogous to them. Many of them were given to favorites. Some of them were issued solely to increase the revenue of the King, who attempted to exact large compensation for the grant. Instead of dealing only with the question of new industries, many of them were issued for the control of those that were well established. Some were in a way the equivalent of a modern protective tariff. Others were ostensibly based upon the necessity of regulating the quality and character of the product. Some of them amounted to but little more than an excise tax. All through this period, however, the encouragement of invention and the introduction of new industries were regarded as of prime importance, and while the monopolies granted by royal authority formed a constant source of trouble, leading repeatedly to conflicts between the King and Parliament, no one questioned the soundness of a public policy that obviously stimulated industrial development. In a leading case of the utmost interest, decided in the year 1603, in which the court held that a patent granting a monopoly on playing-cards was invalid, the successful counsel, who contended strenuously that such a monopoly as the one before the court was contrary to English law, said in his argument.

> Now, therefore, I will show you how the judges have heretofore allowed of monopoly patents—which is that when any man by his own energy and industry or by his own charge and industry, or by his own wit or invention doth bring any new trade into the realm, or any engine tending to the furtherance of a trade . . . that never was used before, and that for the good of the realm; that in such cases the King may grant to him a monopoly patent for some reasonable time, until the subjects may learn the same, in consideration of the good that he doth bring by his invention to the Commonwealth, otherwise not.

It is interesting to note that in this case an argument for the validity of the monopoly was that playing-cards were merely a "vanity"; that card playing involved "the vices of deception by servants of their masters, and the employment of time that ought to be devoted to other interests and not to such enormities" and that therefore "the Queen might prohibit it by patent."

This unsatisfactory condition of things led to what is known as the "Statute of Monopolies", passed by Parliament in the year 1623 and which was the first patent statute. Prior to this, the whole subject of letters patent had been dealt with by the courts, in accordance with the principles of the unwritten common law of England.

The "Statute of Monopolies" declared invalid all monopolies then existing and relating to the "sole buying, selling, making, working or using of anything within this realm or the Dominion of Wales, as contrary to the laws of this realm," and forbade such monopolies for the future. Certain specific grants were excepted, and there was the further general exception that the statute should not extend to any letters patent then or thereafter granted for the limited terms named, which gave a monopoly of the

> Working or making of any manner of new manufactures within this realm, to the true and first inventor or inventors of such manufactures which others at the time of making such letters patent and grants shall not use, so as also they be not contrary to the law nor mischievous to the State, by raising prices of commodities at home or hurt of trade or generally inconvenient.

During the unsettled periods of Charles I and of Cromwell, there were, as might have been expected, many vicissitudes in the development of the patent law, but the principle that had characterized the English law from the beginning, that a patent might be granted as a reward to the inventor and as an encouragement to others, ultimately prevailed in England, while all the other industrial monopolies of the Tudor and Stuart periods disappeared. Such was the situation of the English law and practice at the time of the American Revolution.

In the colonies on this side of the water, there had, of course, been but little industrial development. In spite of that fact, the value of patents had been recognized and a number had been granted. The first to be issued in this country appears to have been granted by the General Court of Massachusetts Bay Colony in October 1641 to one Samuel Winslow for a process of manufacturing salt. The term of the patent was for 10 years and the grant was conditioned upon works being established within the year. In 1656 the Massachusetts Bay Colony also granted a patent to John Winthrop, son of Governor Winthrop, for the "sole privilege of manufacturing salt after his own particular method" for a term of 20 years. A number of other patents were issued in colonial times by Massachusetts, Connecticut and Pennsylvania.

The articles of confederation adopted by the colonies in July, 1776 contained no provision for the granting of patents, but the states issued patents independently as the colonies had done. For example, in 1785 one John Rumsey obtained patents from the states of Maryland, Virginia, Pennsylvania and New York for a new type of boat which during the previous year had been tried on the Potomac river in the presence of Washington.

Those who framed the constitution of the United States recognized, with characteristic wisdom, the importance of encouraging industrial development. It is interesting to note that a proposition was before the convention that prepared the constitution, by which Congress would have been empowered "to establish public institutions, rewards and immunities for the promotion of agriculture, commerce and manufactures." This broad but vague provision was not adopted. In its place, we find in the constitution that authority is given to Congress "to promote the progress of science and the useful arts, by securing for limited terms to authors and inventors the exclusive right to their respective writings and discoveries."

The time has not yet come when we have ceased to admire the far-sighted wisdom of the framers of our constitution. It is one of the most interesting things in history that it has proved so nearly adequate to meet the radically changed conditions of modern times. Many of our most thoughtful men believe that our prosperity and well-being depend to a great extent upon a strict adherence to the underlying principles upon which it is based. In the hands of a long line of eminent judges who have passed upon it and construed it, it has proved its adaptability to social conditions utterly different from those existing at the time when it was prepared.

Whatever may be its merit as a whole, there can be no question as to the singular completeness and adequacy of the simple clause which I have just quoted and upon which our patent system is based. Acting in harmony with the spirit as well as the letter of the constitutional provision, Congress has adopted a scheme of patent protection the wisdom of which has been shown by the results. No one can say how ineffective the clause might have proved if it and the legislation under it had been construed and applied by unwise judges; but the great jurists, from Marshall down, who have developed and fixed the meaning and spirit of other parts of the constitution have applied to this section, with the most satisfactory results, the patriotic and far-sighted intelligence that characterized all their work.

It is an interesting circumstance that this provision of our constitution says nothing as to the promotion of industry or the introduction of new industries. It only refers to the promotion and progress of science and the useful arts. This seems to me to have introduced a radically new idea into the view of the function and scope of a patent system.

The patent system of Great Britain, to which I have briefly referred and which was the only one that had received any development before our own, approached the matter from a different point of view. Its object was to promote progress, primarily by encouraging the establishment of new industries in the Kingdom of Great Britain or the improvement of those already established. The English patent law, from the beginning, was construed as affording to one who brought into England an industry or an improvement from a foreign land, a right to the same protection as that to which he would be entitled if he had been the inventor or the discoverer of that industry or that improvement. The reward of the law was not for inventive achievement. It was for giving to the community knowledge of an art that it did not have before. The man who by reason of facilities for travel or intelligent powers of observation acquired information as to a manufacture long carried on in foreign countries, was exactly on the plane with the man who had originated the idea. This has been a characteristic of many of the important patent systems that have been developed in countries outside of the United States and England. In great part they take the English view. They reward the man who introduces or improves the manufacture and not alone the man who originated the improvement. For the first time in the world, the framers of our constitution laid the entire stress of their effort on the recognition and reward of inventive thought. They adopted the new theory that if men are encouraged to invent by the certainty of reward, or, as Lincoln put it, if the fire of genius were fed with the fuel of interest, the industries will take care of themselves. They believed that there was no way of securing new industries or of making improvements in old industries so effective, as to encourage intellectual effort by way of invention and discovery. As already stated, they ignored the suggestion that there should be other forms of reward for the inventor or discoverer. They authorized only a single reward, a single recognition of his merit, namely, that there should be secured to him the ".exclusive right" to his invention for a limited time. It is to be noted that they did not authorize Congress to give him a right that was less than " exclusive "; nor did they authorize any discrimination as to the personality of the inventor or the magnitude and character of the invention.

It is not impossible that the framers of the constitution fully appreciated the nature and efficacy of the patent system that they were authorizing. If they did, it is only another instance of their far-sighted wisdom and intelligence.

We all know generally the development of the provision of the constitution under the influence of friendly public opinion, sympathetic legislation, and strong, intelligent and comprehensive, judicial interpretation. We have to-day a patent system which is generally regarded as the best in the world. Under it, applied science and the useful arts have been promoted as in no other country and at no other period in the world's history.

Much may be said of some assumed abstract quality in the American mind and temperament which has led to our marvelous industrial development of the last century. Many reasons may be given for the existence of the quality that has made this progress possible. It may be referred to climate, to the influence of democratic institutions, to our system of education, to the fact that we as a community are made up of the more enterprising off-shoots of many races that have here met and under our unique conditions have developed new capacities. There may be a certain amount of truth in each or all of these hypotheses. None of them, however, seems adequately to explain the result, nor are any of these considerations so related to some or all of the others as to make it by any means certain that it is for any such reason that we have advanced in industrial achievement by leaps and bounds. During the period of our greatest development, namely, during the last 50 years, we have been closely associated with all the other great nations of the civilized world. They have known of us and of our work. We have known of them and of their work. There has been a constant interchange of ideas, methods and products of manufacture between one country and another. I doubt if any of us, in view of our knowledge of and relations with the English, French, Germans and Italians, can be satisfied that we have done such great things industrially because of our peculiar situation or by reason of any of the special conditions above referred to.

There can be no doubt, however, that we have had a different patent system administered in a different spirit. Is it not reasonable to believe that this is at least the most important advantage we have had in our industrial work and that because of it more than because of any other consideration, we have attained our great success in applied science and the practical arts? I am quite prepared to admit that many other considerations may have played an important part in our development, but it seems to me certain that that development is largely due to the special character of our patent system and its efficiency in encouraging invention.

What is our patent system: not merely as a statute or provision of law but in its relation to actual affairs? When stripped of all the many refinements that are necessary for its practical application and administration, and when regarded in the simple form in which it is apprehended and appreciated by the millions of people in our community who know of it and are interested in it, our scheme of patent protection amounts simply to the grant to one who has had the intelligence and skill to make an improvement in the useful arts which involves invention, of the exclusive right, for the term of 17 years, to make, use and sell that which he has discovered, invented or designed. Almost everyone in the country knows this much of the characteristics of an American patent. Everyone who has any information on the subject at all, also knows that this absolute right to exclude everyone else from making, using and selling the patented thing for the term of 17 years is one that may be exercised and enjoyed by the patentee exactly as he pleases. He may himself work under the patent. He may sell the entire patent. He may sell a part interest in the patent. He may grant licenses in any form he chooses to any number of people, provided his licenses are consistent with each other. He may give one a right to use only; another a right to manufacture and sell. He may give to one a right, exclusive or non-exclusive, to apply the invention in one field and to another an equally valid right, exclusive or non-exclusive, to apply it in another field. There is no limit to the inventor's absolute control of the thing that he has invented, within the limits of honesty and fair dealing imposed by law generally on all transactions.

Moreover, everyone knows that the cost of taking a patent is ordinarily not great and that once the patent is granted, it remains in force for 17 years without any further expense to the patentee. He is not obliged to work under the patent, nor is he obliged to make any use at all of the invention unless he chooses. The law recognizes that such a requirement is not needed. Self-interest and a desire to get a return from the invention, will be quite enough to stimulate the inventor or patentee to effort and to insure commercial development of his invention, if it has any value. At the end of the term, the patented invention is free for all to use.

If capacity for invention can be stimulated at all, there could be no more effective means of exciting it to the utmost than the opportunity of securing just this reward which our patent system gives. Every one of our industrial workers and a vast number who are not engaged in industrial effort, know that if they have a new idea which amounts to invention, in any one of the useful arts, they may monopolize that idea for the term of 17 years. Short as is this period measured by some standards, it seems and is long as compared with the period of the activity of the individual. The inventor may recognize that there is no immediate market for his invention. If, however, he feels that his idea is a good one, he will work it out and patent it with the hope, amounting in most cases to a belief, that during the 17 years of the life of the patent, the art will develop so as to make his idea of value to him. If he is a poor man absolutely unable to go into business on his own account, he feels that if he gets his patent, he has a substantial length of time during which he may seek for help in the commercial introduction of his invention, work up enthusiasm for its exploitation, find a purchaser for it or licensees who will work under it. The manufacturer who is not only concerned with the successful application of his present industrial methods but is looking forward to their improvement, or who is seeking for new things to manufacture, is ready to take hold of new ideas, whether developed in or outside of his own factory, to experiment with them at a large expense and to secure a patent on them, even though he knows that he can not immediately utilize them. He is glad to take the chance that years later the ideas which he thus controls may fit into his industry and become of profit to him for part of the 17 years during which he controls them. The capitalist, large or small, always ready to risk his money in the chance of a substantial return, will take up with a new invention even if he clearly sees that years, during which his disappointments may be great and his expenditures large, are sure to elapse before he can hope to make the fortune which he is after, for he believes that his time for profit will come during the latter years of the 17-year term of the patent. The result is that there is the strongest stimulus to manufacturers, employees and capitalists, and even to those who are not directly in touch with industrial operations, to seek out new ideas, new devices, new methods and new structures and to patent them, because they have the assurance that if the patent is once obtained, the invention will be controlled absolutely for the term of 17 years during which it may have value, and that if at any time during those 17 years there is a demand for it, it can be handled, as a matter of right, in that way which is most advantageous to the owner. Under these circumstances they are willing to take large chances.

Almost every one knows the uncertainties of patents and patent enterprises. Almost every one appreciates, what is probably the case, that the greater number of patents never prove to be of value; no one may find it profitable to use the invention for which a patent is taken. Many enterprises, based upon patents, fail for one reason or another. But the chances of success, even if they are no more certain than in the case of those who seek for gold in the bowels of the earth, are quite sufficient to justify even the most prosaic man in an enthusiastic effort to promote the useful arts if he has the inventive faculty himself, or to contribute his time or his money to such promotion, as manufacturer, business man, or capitalist, if he comes in contact with an invention that seems to him promising.

As a rule, the systems of foreign patent law are less liberal than ours. The term of the patent is often less than 17 years. It is sometimes more expensive to secure the patent, and not infrequently, after the patent is once obtained, the inventor can not look forward, as he can in this country, to enjoying the right to his monopoly for the term of the patent on exactly the basis he chooses. In some countries he has to face the payment of onerous fees annually or at an interval of a few years, and if such payments are due at a time when he is out of funds or discouraged, as all patentees and patent owners are likely to be even if the invention is one of great merit and sure to be ultimately successful, the patent may be lost for non-payment of the fees. In some countries, the patentee or those interested in the invention have to look forward to the forfeiture of the patent if there is no manufacture under it within a certain limited and often a very short period. It may well be that this period will expire before the art is ready for the invention or before the invention is commercially perfected or before capital can be secured for its development. In some countries the owner of the patent may be forced to grant licenses, the terms of which are fixed without his consent, and be thereby deprived of that control of the invention which is essential to its profitable exploitation.

I believe that if any such provisions had become part of our American patent system there would have been nothing like the same effort on the part of our people to promote the progress of the useful arts as has characterized them from the beginning, and particularly during the last 50 years.

Even as it is, there is discouragement enough to our inventors and patentees. Although our patent system is, in my opinion, the best in the world, the administration of it in the Patent Office and in the Courts involves difficulties and annoyances to the patent owner which in some cases seem to him intolerable. For example, no one can be sure that the patent which he gets is valid, nor as to its scope. The Patent Office does admirable work but, of course, sometimes errs and the entire art can not be known to it. The uncertainty in the application of the law to the facts, which is naturally greater in patent causes than in most branches of the law, makes it a difficult matter to foresee how a patent will be viewed and construed by the Courts and leads to more or less conflict in judicial decisions. This is a great evil, affecting not only the owners of patents but the public generally, which is unable to come to a sound conclusion as to its rights even when acting under the advice of competent counsel. What will be the finding of the Courts on questions of validity and scope can not be foreseen. The methods of taking testimony in patent causes are cumbersome and expensive. It seems certain that an intelligent and well-directed effort on the part of the patent bar and the Courts could bring about a reform in this direction.

Such evils characterize the practical operation of all human institutions. We can only hope to minimize them.

It is not at all impossible that the establishment of a single Appellate Court to take the place of the nine independent Courts of Appeal now existing would go a long way towards helping the situation. Such a Court would surely bring about harmony of judicial decisions to an extent that does not now exist. It could also criticize intelligently and forcibly the present methods of taking testimony, and stimulate the inferior Courts and the bar to deal wisely with this important matter.

The Patent Office can undoubtedly be organized to do more effective work in its examination of applications. On its judicial side in interference controversies, where it has an organized machinery for trying out cases of priority of invention, there is the same cumbersome and expensive procedure that characterizes trials in Court, with the added hardship of an excessive number of appeals. This also could and should be reformed.

The difficulties of the American inventor and patent owner, great as they are, and they have been so great as to lead some to express disgust with the entire patent system, are due not to the law but almost altogether to defects, some of which can never be eliminated, in the ancillary machinery of the law; and although inventors, patentees and the owners of patents have in individual cases undoubtedly suffered hardship from the inadequacy of the procedure devised to secure and to maintain the rights vested in them under the constitution, if we look at the matter in a large way there is no doubt whatever that the patent system of the United States has to a notable extent stimulated invention and encouraged and rewarded inventors.

In criticizing the procedure of the Courts and of the Patent Office, we must not overlook the inherent difficulties of the situation. The problem is so complex and the administrative machinery has grown up under such conditions, that it is almost wonderful that a more serious situation has not developed. It is to be deplored that there is so much expense, trouble and uncertainty in the administration of the patent system, but it would be much more unfortunate if the law was wrong or if there was, in general, substantial injustice in the grant of patents or the protection of rights and of industries carried on under patents. This I am sure is not the case.

It is easy to find fault with the Courts and the Patent Office for apparent or real error in special cases or for ineffective and cumbrous organization and methods of procedure. All human institutions are subject to the same criticism. I am glad, however, to have the opportunity of expressing my own belief, that the Patent Office of the United States, hampered as it has been by inadequate appropriations, insufficient facilities and the pressure of work that has increased faster than the organization necessary to handle that work could be developed, has been, on the whole, more efficient than any other administrative department of our government, Of one thing I am sure, that in no department has there been greater intelligence or greater honesty and sincerity of purpose. Further, I believe that nearly all who are competent to judge, agree with me that the work of the United States Courts in patent causes has been of a high order and is entitled to great praise. There has never been a question as to the good intention of those Courts and the certainty of their earnest effort to apply and develop, logically and fairly, the constitutional theory upon which our patent system is based. It has not been much of a disadvantage to the patent system or to patentees that the judges have as a rule had no special technical training. Their lack of such training has simply made their work more strenuous. While undoubtedly, as in all other branches of the law, cases relating to letters patent have been wrongly decided, the conclusions of the Courts of the United States on patent matters as expressed in the recorded opinions, have been characterized to a marked degree by a sympathy with the spirit of the constitution and the law, and by an intelligent and straightforward application of principles to facts of an unusually difficult and complicated character. The record is most creditable.

But whatever discouragement to invention exists by reason of imperfections in the work of the Patent Office and of the Courts, it is a matter of common knowledge that we in this country have the benefit of a patent law which stimulates and encourages invention to a marked degree. The condition of our industries as compared with those in other countries is proof of this, and proof of a higher order than any statistics that are available. What statistics there are, serve only to confirm this view. For example, in 1903, the last year as to which I am able to get information as to all the countries, there were issued in the United States 31,046 patents (50,213 applications were filed in that year), while in the three other great industrial countries, England, France and Germany, there were issued in the aggregate 36,110 patents.

It is a familiar proposition that patent protection exists primarily, not for the benefit of the inventor, but for the benefit of the community. It is easy to argue that an inventor should have a property right in his invention, exactly as an author should be allowed to control for his own benefit, his ideas and form of literary expression which he is under no obligation to give to the public. We all instinctively feel the justice of such a contention. But the right of the inventor as well as of the author, so far as it exists in theory, is of no value to him unless protected by a definite rule of law, and the extent and character of the protection so to be granted is to be determined by the community in view of its own interests. If it were the sentiment of the people that all the protection an author should have would be the exclusive right to his work prior to publication, and that the right of the inventor should be limited to the monopoly of his invention so long as he could maintain it as a trade secret, the only ground upon which law or legislation to that effect could be properly criticized would be as to its wisdom or expediency. Exactly as the whole civilized world has come to the conclusion that the author's abstract right should be recognized by securing to him a monopoly of his publications for a limited time under conditions more or less wise and liberal in the different countries, and this not merely or so much with the view of rewarding the author as to encourage authorship, so the patent systems of the world agree in giving legal sanction to property in inventions, partly because of the feeling that the inventor has some abstract right in them, but for the most part as a matter of public policy to stimulate and secure the promotion of the useful arts.

It is not alone by the specific disclosure of particular inventions that the public gains from our patent system. Inasmuch as a United States patent is particularly attractive because of the fact that the expense of getting it is ordinarily not great and when once obtained there are no further payments to make, and no danger of forfeiture for non-working or for any other reason, so that the patentee has the legal right to control his invention and utilize it as he pleases for his own advantage for the term of 17 years, most of the important and significant inventions made anywhere in the civilized world are likely to be patented in this country and thus disclosed to our manufacturers, inventors and technical men soon after they are made. The Official Gazette of the United States Patent Office prints every week the claims of all the patents issued in that week. Copies of each patent may be obtained for 5 cents each. The result is that in every art there are many who read every patent relating directly or indirectly to their work. Thus all new ideas are promptly circulated throughout the community and immediately brought home to those who are capable of apprehending them and working from them.

Every invention is potentially the cause of others. The study of a new idea whether developed in England, France or Germany, or the United States, when explained in a patent, excites many persons not merely to improve upon the specific form in which that idea is embodied in the patent, but to work out alternative schemes for accomplishing the same result. It is not infrequent that the reading of a patent specification leads to the invention of an important improvement in a radically different direction, because of the train of ideas which arises in the mind of the reader and which might never have been excited except for the disclosure of the patent. Our patent system, therefore, does not merely stimulate invention by promise of reward, but it affords a basis for new ideas by bringing to those who have the inventive faculty just the kind of information and inspiration needed to start them on lines of thought or of investigation that will lead to the promotion of the useful arts.

It is sometimes suggested that our patent system should discriminate against foreigners. The policy of our law from the beginning has been almost without exception directly the other way. I am satisfied that there should be no change in this policy. Not only is our industrial progress stimulated by that immediate knowledge which we get from the patenting in this country of inventions made in foreign countries, as to which we otherwise might not be informed for years, but the issue of such patents gives our industries the benefit of the use of inventions made abroad much earlier than would otherwise be the case.

Sometimes we buy or take licenses under the patents granted to foreigners. Sometimes, although less frequently, the foreigner establishes an industry in this country; but in all cases we get an early knowledge of the foreign work that is of great value as an exciting cause of further invention.

The extent to which, in the aggregate, inventors and those who supply the capital necessary for the development of inventions actually make a profit out of patents in this country is an open question. It may well be that there has been a loss rather than a gain from patents to the individuals who have secured and worked under them. That the community is the gainer from the patent system is altogether clear.

Let us consider for a moment the way in which work is done and applied science and the useful arts promoted under the stimulus of our patent system.

Those who invent may be divided roughly into classes. The first to which I shall refer comprises the individual inventors to whom once or several times in the course of their lives occurs an idea that seems likely to be of value in the industries. Such an inventor may be of any station in life or of any occupation. The idea may be suggested to him by his work or by accident. If he has faith in it, he develops it, puts it into practical form, either on paper or by actual experiment or construction, and patents it, making in the specification of his patent the full disclosure of it that the law requires. He gets nothing by his patent except the right, for 17 years, to exclude others from making, using or selling his invention except on terms satisfactory to him. Frequently he is without means. Sometimes he has business experience and capacity but often he is utterly incapable of developing or handling a business enterprise. Sometimes he is in such relations to others as to know where capital and business experience are available for promoting the particular invention he has made. Not infrequently, he has not the remotest idea where he can find either. In this matter, a great deal depends upon whether his invention is one definitely germane to an existing art, or radically new or at variance with the prevailing methods and tendencies of the industry to which it is related. Sometimes he is utterly incapable even of putting his new idea into commercial shape where it will be of value to the community and has to secure the help of engineers or inventors of a more practical turn of mind before his invention is embodied in a form which has any real utility.

The value of a patent issued to such an inventor, to him and to the community, depends as much on the inventor's skill or good fortune in introducing his invention into actual use as upon the merits of the invention.

It is probable that the vast majority of patents issued are of no real importance. Many of them are for definitely worse contrivances or distinctly more inefficient ways of getting at the result than others already in existence. Many are based upon radically wrong principles, although they seem to involve ideas that are not only practically effective but brilliant in their ingenuity. Frequently an invention is made years before the art is ready for it, and even the most diligent and intelligent efforts can not advance the art to the point where it will utilize the invention. In many, and perhaps in most cases, the commercial success to be obtained in working out any specific patented invention is a gamble only comparable to the gamble of the mining promoter who seeks to develop a new mine from surface indications.

The invention of the telephone was made by an individual inventor whose name will be forever famous in the annals of science and industry. While the result of that invention has been the creation of one of the most far-reaching and important pieces of our modern industrial and social machinery, it is easy for those who are familiar with its early history to see that it might have failed to secure any recognition except as a scientific toy. While the greatest credit is due to Professor Bell for his invention, it is almost equally to his credit that within a comparatively short time after he had solved the problem of the electrical transmission of speech, the wonderful possibilities involved in that invention were definitely foreseen by him at a time when few men had even a glimmering of its real commercial importance. In spite of Professor Bell's clearness of vision, the development of the invention might have been indefinitely postponed; in fact it might never have become such an important part of our social and industrial machinery; if he had not been fortunate enough to find, while his patent was still young, the right capitalists and the right business men to do the work of organizing, developing and financing the industry.

Sometimes these individual inventors find their capacity for originating new ideas so great that they adopt invention as their profession. Of this class of inventors, our fellow-member, Mr. Edison, is perhaps the most conspicuous. It is unnecessary to remind this audience of the wonderful fertility of his inventive genius or the wide range in which he has done marvelous work for the advancement of the useful arts.

Such professional inventors occasionally work with their own capital, and some of them show capacity for embodying their inventions in practical form and the requisite business ability to direct to a greater or less extent the commercial introduction of their inventions. But this is not always the case, and with them as with other classes of inventors, it is generally essential that their inventive faculty should be supplemented by the capital and business energy as well as the technical and inventive skill of others, in order that the joint efforts of all concerned may result in a real improvement in the useful arts.

With them as with the man who makes but one invention, it is only because of the protection afforded by the patent system of the United States, that capital and business experience can be diverted from standard occupations to the chances of an enterprise based upon new inventions. There are too many well-known instances of the absolute failure of what seems a promising invention to make it possible to attract capital and business ability to the inventor's support unless, because of patent protection, there seems to be an opportunity to secure a return commensurate with the risk involved.

The history of the telephone industry also affords an illustration of the activities of another conspicuous class of inventors, whose work under the protection of the patent system of the United States is most effective, and of the conditions under which they make their contributions to the progress of the useful arts.

The business men and capitalists who took hold of the telephone enterprise in the early days, would never have risked their time, energy and money, if they had not believed that by reason of their fundamental patent they could exclude all the people of the United States from making, using or vending telephones without their consent, not for a period too short for effective work, but for one that was reasonably long, namely, 17 years. They undoubtedly foresaw, although very inadequately, that the business upon which they were entering would be full of disappointments; that only by the exercise of the utmost ability and energy could it be made to succeed; that a very great investment would be required; that large sums would have to be spent in engineering and in perfecting apparatus and that they would have to run the risk of judicial decisions as to the validity and scope of their patent. In going on with the enterprise, they took their chances with all these contingencies, hoping and believing that in spite of them, they would secure an adequate profit.

From the very beginning it was clear that the telephone invention in and of itself could be of value only when supplemented by many other inventions which would be found necessary in the effort to make the main invention commercially effective.

Because the business men of the organization knew that suitable apparatus must be developed, and that every added invention would strengthen their position not only during the 17 years of the main patent but during the 17 years' term of each and every one of the patents taken out on subsidiary methods and devices invented during the progress of commercial development, one of the first steps taken was to organize a corps of inventive engineers whose duty it was to make every effort to perfect and improve the telephone system in all directions, first, that it might become of greater commercial value; and, secondly, that by securing accessory inventions, possession of the field might be retained as far as possible and for as long a time as possible. The result has been a very great number of patents taken by the engineers and inventors of the Bell company for inventions in, or relating to telephones or telephonic apparatus. Moreover, the patents of others were studied with the utmost care and an innumerable number of outside inventors found a ready market for patents which they secured on their contributions to the telephone art. It is not impossible that nine-tenths of the patents so acquired were for inventions which proved to be of no real importance in the development of the art, but taken all together they have made the mechanism of the business and have given us the wonderful system of telephonic intercommunication that we have to-day. Without the stimulus afforded by the patent laws of the United States, it seems to me certain that the telephone art would not have attained its present situation in the social and industrial organization of to-day, in many times the number of years that have elapsed since Professor Bell's invention.

In the same way, in practically every manufacturing and technical organization in the United States, careful attention is given to the promotion of the particular art, whatever it may be, by the employment of men who have shown the requisite capacity, to make inventions relating to the special industry. Many such inventors are under definite contract to assign their inventions to their employer, receiving compensation for this sort of work either directly or in the form of a salary. If the individual workman in such an establishment who is not under contract makes an invention, it is apt to be acquired as part of a general policy which the employer has adopted and to which the employees have assented, on terms that are agreed upon.

Very many of these inventions make no real impression upon the art and are simply a source of expense and annoyance to the manufacturer. The justification of the manufacturer for the outlay, and the energy devoted to invention in his establishment is found in a general advance in the quality and character of his output and in economies and improvements in operation, the specific value of which can not be estimated but whose general importance is very great.

I have in mind a particular business enterprise based upon patents which will in a short time, by the introduction of new machinery, have released the labor of not less than 100,000 skilled operatives in this country for other kinds of work than that upon which they were formerly engaged. I knew of the inventions upon which this enterprise is based from the time of their inception. It occurred to an experienced manufacturer, not himself an inventor, that there could be a revolutionary improvement in a certain standard machine. He employed skilled mechanics of inventive capacity to work upon an idea, not in itself involving invention, which he was able to state to them with sufficient clearness. One set of machinery after another was devised, constructed and thrown into the scrap heap. Finally, after the expenditure of more than $300,000, the manufacturer was able to put his first machine into commercial use. More than a million dollars had been invested in the enterprise before there began to be any return. Repeatedly since then very large expenditures have been required to secure further inventions needed to perfect the apparatus. Although the enterprise to-day is a great success, changes are still constantly made in the mechanism, for which changes patents are taken.

If it had not been for the patent system of the United States, the manufacturer would never have even contemplated the development of this machine. If there had been any provision in the statutes by which any patent which he acquired would have been forfeited unless manufacture under it had begun within a relatively short time, as is the law in Germany and elsewhere, he would not have touched the enterprise.

The question is sometimes debated whether or not under the patent system of the United States the inventor himself obtains the share of patent profits to which he is justly entitled. If he does not get his fair proportion of such returns as are due to his invention, the fault is not with the patent system, for the whole matter of dealing with his invention is in his own hands. No one except the true inventor can obtain a valid patent and he need neither work under it, assign it or any part of it, nor grant licenses under it unless he chooses. In so far as there is any foundation for the contention that under modern conditions, the inventor himself does not get all that he should for his work, the basis for the contention is not the patent system or the law, but the social and industrial conditions which prevail.

It may be argued with equal force and with the same reasonableness or unreasonableness that capital gets more than its share of the return from industrial enterprises as a whole, and without regard to the patent features which are merely incident to them. If wages are lower than they should be under ideal conditions, if salaries of engineers and executive officers are less, it may well be that the inventor fails to get his share, and for the same reasons, which are based solely upon the principles upon which society is organized as the result of an evolution of thousands of years. A discussion of this broad question is outside of the scope of this paper.

No statistics are available on the point, but it is my own impression that there is no valid foundation for the suggestion that inventors are not adequately compensated. It is undoubtedly the case that in individual instances, meritorious inventors fail to secure all to which it might be said that they were fairly entitled as a reward for their work. It is equally true that other things than merit determine to a large extent the reward of the professional man, the artist, the architect and the engineer. It probably would not require very close analysis to show that in very many cases the material reward of the business man and the capitalist is not at all proportionate to his individual merit. Accident, opportunity and particularly the fitness of the particular man for the special environment in which he happens to find himself, have much to do with all forms of reward that come to men whether in the goods of the world or in reputation. This is as true of the inventor as of other men; but taking inventors as a whole, I do not believe that they have cause to complain.

To many of them their inventive capacity is part of their stock in trade. Because they can invent, they receive substantially more by way of salary and standing than would otherwise be the case; as do those who are deft in the use of tools or who show skill as designers or capacity as salesmen. In many instances, some of which have come to my personal attention, the inventor is the only one who has made any profit out of an enterprise based on patents, his associates the capitalist and the business man having suffered great loss. In other instances, both the inventor and his associates have been adequately compensated.

In dealing with this whole question we are apt to overlook the fact that by far the greater number of inventions, particularly at this late stage of the older arts, are mere details of improvement or alternative devices or methods from which, regarded specifically, no large amount of profit can be made by anyone. Such inventions are only valuable as incidents to a manufacture. They can not be segregated and appraised independently.

In spite of occasional cases of hardship such as occur in every business and profession, I believe that the ordinary social and business principles which, irrespective of the patent law, determine the distribution of the profits of invention as between the inventor, the capitalist and the business man, result in securing to the inventor, on the average, as large a portion of that to which he would be entitled under ideal conditions (such as never can be attained) as come to any other workman in our vast industrial army.

In this paper I have not undertaken to deal with the many special features of our patent system which are of great interest, nor to point out to any extent the details in which according to my own opinion the law is defective or capable of improvement. It is quite probable that the amendments to the law which I should suggest would be as unwise and ineffective as are, in my opinion, most of those made by others. I have only sought to call to your attention some of the underlying principles at the basis of our patent policy and to show how those principles seem to me to work in practice. If I am right in my belief that we have a fair and reasonable patent system which promotes the progress of the useful arts more effectively than any other that has been devised, and that to the beneficent operation of our law is due to a large extent our recognized position of supremacy in the industries, I trust that you will all agree with me that our system of patent protection is entitled to that hearty support and friendly consideration which I believe it to have generally throughout the United States. No human institution or human law is perfect. We all know that there are some provisions in our patent statutes that might perhaps be amended to advantage. We all know that our patent laws like all other laws work hardship in special cases. We all know that sometimes they result in individual instances of injustice, although it is more than probable that there would be a great divergence of opinion as to the particular cases in which there was such injustice. Generally speaking, however, it seems clear that in eir present form and with their present spirit as they have been developed and applied by the Courts, they are among the most effective agents for the promotion of our national and individual prosperity and as such entitled to the cordial support of all. They are particularly entitled to recognition as a social and industrial force of the utmost importance by the members of this body, many of whom are inventors of a high order and all of whom are definitely engaged in lines of work which probably could not have been developed to their present state of relative perfection in a thousand years from the date of Faraday's work and the construction of the Gramme machine, if it had not been for the stimulus of the patent systems of the world, and in particular of the patent system of this country.

A paper to be presented at the 26th annual convention of the American Institute of Electrical Engineers, Frontenac, N. Y., June 28, 1909.

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AUXILIARY POLES FOR DIRECT-CURRENT MACHINES
Their Electrical Design and Method of Testing

BY JOHN N. DODD

This paper discusses the design and testing of auxiliary pole machines, from the standpoint of conceptions developed by the author during a rather extensive practical study of the subject. It was at a time when there was very little theoretical information to be had, and when as a consequence, the result of tests often seemed to be confused and even misleading. The paper is therefore, primarily intended for those who are interested in the practical design and testing of such machines, and if the results are of assistance to any such persons, it will be a source for gratification.

The subject matter is original with the writer. The method of testing which follows directly from the principle developed is presented here for the first time, and is of great importance to those engaged in designing or adjusting auxiliary coils, as it permits the exact checking of calculations, and what is of greater importance, it makes it possible to adjust the coils correctly for all loads, speeds and voltages, by means of tests at a single load, when conditions do not allow of testing the machines at full load at the proper voltage and speed. It is also hoped the paper will be of interest to that larger class of members who are interested in the subject from purely theoretical grounds and who wish to keep informed on one of the most important recent steps in the design of direct current machinery.

This advance in design of direct current machines is generally considered a recent step, but actually the subject has some claim to age. Auxiliary poles were patented by Mather, an American, in the year 1885, or possibly earlier. They were adopted by

Frank J. Sprague in the motors used in his experiments on the Manhattan Elevated Railroad during the years 1885 and 1886. These early developments were, however, far in advance of their day. At that time the general laws of commutation were not well understood, and the commercial requirements were not so exacting in the matter of overload capacity, sparkless operation and cost, as at the present day.

Before dealing with the subject of auxiliary or commutating poles, it is necessary first to refer briefly to the general principles of commutation. Fig. 1 is the conventional diagram of armature, commutator and brush, showing the direction of current in various parts of the circuit. The word commutation is derived from the fact that the direction of current in each successive coil is reversed, due to the movement of the brush. If the contact surface of the brush is ample for the current collected, the phenomenon known as sparking, can be caused only by certain portions of the brushes carrying an excessive amount of current. This heats the brush and the commutator to such an extent that it volatilizes parts of one or both of them. Perfect commutation occurs when the current is divided equally over the surface of the brush. This agrees with the condition that the rate of reversal is the same at all points.

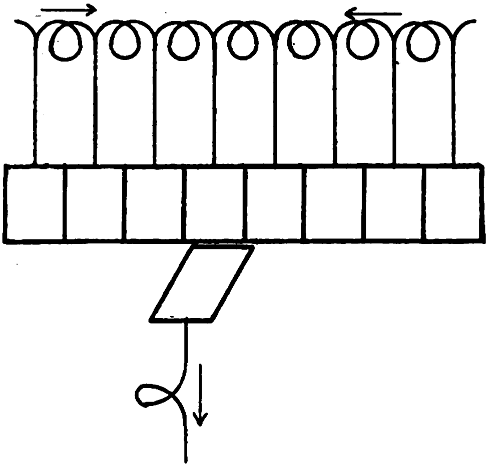

Fig. 1

In order to obtain this three conditions must be present.

1. Each bar must make perfect contact with the brush over

its entire surface. This is a mechanical question which will not enter further into this discussion.

2. The resistance of contact surface between brush and bar must be high with respect to the resistance of the coils, or of the connections to the commutator, otherwise the edges of the brush will carry more than their share of the current. This is a condition which is filled by practically every direct current machine with carbon brushes and, therefore, will not be further considered.

3. There must be no electromotive force generated in the coils short-circuited by the brush. This is the matter of greatest importance to all designers of direct current machinery. It is the electromotive force in these coils that causes most of the poor commutation experienced in such machines. If all magnetic action on the commutated coil can be annulled and the current be collected by the brush according to Ohm's law, the commutation would be perfect.

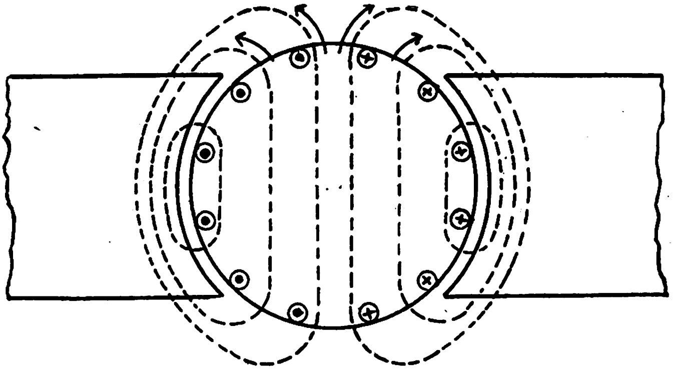

FIG. 2

The cause of an electromotive force in any coil is, that the coil cuts magnetic lines. Magnetic lines in a machine come from two sources. In the first place there is the flux of the main poles. If, however, the brushes are at all loads left at the no-load neutral, the commutated coils will be at a point where there is no flux, due to the main poles. The flux which causes trouble is a flux which appears with the load. Fig. 2 shows the source of this flux dependent upon the load. An armature is a mass of soft iron. With a pitch winding, the effect of a current flowing through the armature coils is the same as if the armature were surrounded with a spiral coil of wire carrying current and, therefore, producing a flux essentially as shown, at right angles to the flux of the main poles. This flux has a maximum density at the point of commutation. It is the motion of the armature coil past this armature magnetization which is the source of the electromotive force generated in the commutated coil. The well-known distorted field of full load, is the resultant of this flux with the flux of the main pole.

This armature field may be measured by taking the distribution curve at full load and at no-load, brushes at no-load neutral. The full-load curve is the resultant of the no-load curve and the armature curve, and the armature curve may be obtained from a proper combination of the no-load and full-load curves. The armature curve obtained in this way will be correct for all points, except for those coils under the brush in which the collection of current by the brush vitiates the results. Even at this point, however, a reading of 3 volts or higher, may be observed.

If at full load, this armature flux can be annulled, and in particular that part of the flux which passes through the commutated coil, the result would be equally good commutation at full load as at no load. The entire paper is a development of this sentence and for this reason attention is drawn to it here. The expression is ordinarily used, that to obtain perfect commutation a reversing field must be supplied which will force commutation. Such an expression presupposes that electricity has inertia which must be overcome. The principle presented in this paper is, that an annulling field must be supplied which will allow commutation.

It should be noted that the armature flux, as stated above, is identical with the flux of armature self-induction, as defined and calculated from ordinary practical formulas, although the statement of such formulas often gives a different conception. According to the usual definitions, and the formulas for calculating it, the flux of armature self-induction surrounds each armature slot, and it is the dying away of this flux, and its growth to full value in the opposite direction that is the cause of the electromotive force of self-induction in each coil.

While such a conception is basically correct, it will, if it is not pushed to its logical limits, lead to the conclusion that except for those teeth in the commutating zone, two sets of magnetic lines pass through each armature tooth in opposite directions. In the final summation these two sets of lines annul each other, and the resultant flux lies as shown in Fig. 3. This is the resultant flux that is referred to in this paper as the flux of armature self-induction.

If there is placed over the commutated coils a pole of magnetic material, the flux of armature self-induction will be increased, due to the increased permeability of the path. If this pole is excited with a coil of the same magnetomotive force as the armature, but opposed to it, this additional flux will be annulled, but the original flux, the flux of armature self-induction, will be left unchanged. There must be added to the auxiliary coil a sufficient magneto-motive force so that the flux, which in Fig. 3 emerges from the top of the teeth and lies across the slots in the commutation zone, may be supplied from the auxiliary pole instead of from the armature, and in addition, a sufficient number of lines must enter the armature to equal the self-induction of the armature end connections.

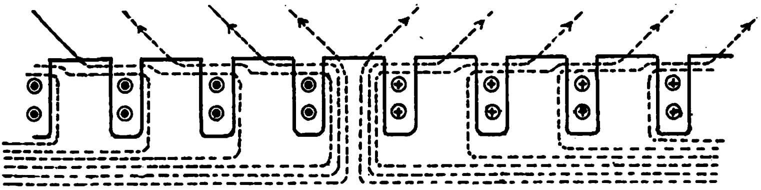

FIG. 3

With these facts in mind, one is in a position to consider the design of an auxiliary pole from a purely electrical standpoint.

ELECTRICAL DESIGN.

Necessary data. The first step in the design of an auxiliary pole, is to calculate the voltage of armature self-induction. This is usually not a difficult matter, for there are in use a number of good formulas for what is called, with some looseness, the " sparking constant ". This is usually equal to, or from it can easily be derived the volts per bar of self-induction. The factors contained in such a formula should embrace; the frequency of commutation, the current in the commutated coils, what is known as the slot constant, and an allowance for the self-induction of the armature end connections. The volts per bar of armature self-induction, have the same value as the instantaneous voltage which must be induced in the commutated coils by the auxiliary pole. Knowing the instantaneous voltage and the peripheral speed of the armature, the flux density necessary over the pole-face can be calculated.

Pole tip. It is not necessary, and is often undesirable, to make the pole and the pole-tip of the same size. The pole must be of sufficient size to carry the flux of armature self-induction, while the pole-face or tip must be wide enough to cover the zone of commutation; that is, the pole-tip must cover the extreme positions occupied by any of the armature coils at the time they are commutated. Whether or not it is advisable to make the pole-tip wider than this, is a point open for discussion. Against the wider pole-face are the important arguments of space required, increased magnetic leakage and decreased ventilation. Moreover, the auxiliary pole must supply, not a given flux, but a given flux density per inch of periphery over the commutated zone. Consequently, for a given air-gap density, the total auxiliary-pole flux is proportional to the pole-face, and with a given pole-core the wider the pole-face the sooner will saturation of the pole be reached. Against these arguments it may be stated that if a wide pole-face is an advantage, it usually costs very little to make the auxiliary pole of ample size, and no electrical troubles are experienced if the pole-face is wider than necessary.

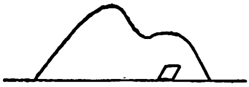
FIG. 4

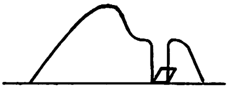
FIG. 5

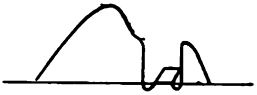
FIG. 6

Figures 4, 5, and 6 show the effect of auxiliary poles on the full load distribution curves. Fig. 4 is the distribution curve of a direct current machine at full load, with brush at the no-load neutral showing the distorted field.

Fig. 5 gives the distribution curve of the same machine with auxiliary poles of the necessary width and correct strength.

Fig. 6 gives the distribution curve of the same machine with auxiliary poles slightly wider than necessary.

It will be noted that in both Fig. 5 and 6 the coil emerges from under the brush into an active field, but in Fig. 6 the field is very weak, and it reverses almost immediately; that is, if a spark should form under the brush there is less probability of its being carried beyond the brush, if conditions are as shown in Fig. 6, than if they are as shown in Fig. 5; from this point of view a wide pole-tip is of more advantage than a tip of exactly the width of the brush.

From these three figures can be noted the particular difference between a motor and a generator. For a generator, the motion of the commutator is toward the right, for a motor it is toward the left. In a generator, the coil emerges from under the brush into an active field, which rapidly dies out and reverses. In a motor, the coil enters a field which rapidly grows stronger, and does not die out until the coil has almost reached the succeeding brush.

The general conclusions from this are: first, there is a greater tendency to flash over in a motor than in a generator. second, a wide pole-tip is of special advantage in a motor, on account of its effect in introducing a definite space between the brush and the active field. At the same time it must be said that the disadvantages of a wide pole, in respect to leakage and ventilation and space, are most evident in certain motor designs; for example, railway motors.

Professor Arnold has given the correct width of pole-tip as:

$$Br + T - b$$

Where

T = Distance between slot centers.
Br = Thickness brush reduced to armature diameter.
b = Thickness commutator bar reduced to armature diameter

A slightly different form is:

$$\text{Thickness brush} \times \frac{\text{Arm. dia.}}{\text{Comm. dia.}} + \frac{\text{Arm. Circum.}}{\text{No. slots}} - \frac{\text{Arm. Circum.}}{\text{No. Bars}}$$

Size of poles. The auxiliary pole prevents sparking, by providing a magnetic flux which neutralizes that part of the armature flux passing through the commutated coils. It should do this at every load up to the specified overload, without any adjustment of the auxiliary coil-winding; in other words, the flux passing through the auxiliary-pole should be proportional to the load, or the pole must be unsaturated up to the specified overload limits. It may be of interest to consider this matter further. The flux of armature self-induction varies directly with the armature current; or, in other words, according to a straight line which is fixed for any machine, as shown in Fig. 7.

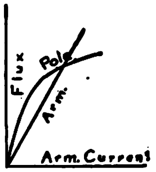

FIG. 7

The current passing through the auxiliary coil is a certain proportion of the armature current. It is, therefore, possible to plot the curve of auxiliary-pole saturation in terms of armature current and auxiliary-pole flux. For any machine, this curve is not a constant, but can be changed by changing the proportion of armature current passing through the auxiliary-coil. Such a change will alter all the abscissæ of the curve in the same proportion. When all the armature current passes through the auxiliary-coil, these abscissæ will have their minimum value, and the curve of auxiliary-pole flux will have its maximum slope. If for a certain adjustment of the auxiliary-pole the two curves of armature induction and auxiliary-pole flux are plotted, the vertical distance between these two curves at any load, measures the flux cut by the armature coils at that point, and is therefore a measure of the sparking tendency of the machine. To ensure sparkless commutation this vertical distance should be zero, for any load up to the maximum overload specified, and to obtain this, the proportion of current passing through the auxiliary-coil must be adjusted until the two curves coincide.

Two cases occur where this coincidence is impossible.

1. Not enough turns on auxiliary coil.

In this case the curve of pole magnetization will always lie to the right of the curve of armature magnetization. This can be remedied in two ways, either by reducing the air-gap, or by increasing the number of turns on the coil. If the length of the auxiliary pole-tip measured parallel to the shaft is less than the length of the armature core, the desired result may be obtained by increasing the pole-tip length. It is useless to increase the size of the pole-tip measured along the circumference, because, as has already been pointed out, the effect of the commutating pole depends not on the total flux but on the flux per inch of periphery across the zone of commutation.

2. Auxiliary pole saturated at maximum load.

In this case the only real remedy is obtained by supplying a larger set of poles. If the pole is badly over-saturated the sparking will be vicious. If the over-saturation is slight, matters may to a certain extent be compromised by adjusting the auxiliary pole shunt so as to have too strong a pole at light loads, and too weak a pole at heavy loads. Very little relief, however, is possible in this way, especially for high-speed machines. At all loads but one there is a tendency to spark. Even at that one load, results are often unsatisfactory; in other words, the only satisfactory results are obtained when the two curves coincide absolutely up to the maximum load which must be carried for sustained periods. For greater loads which occur for short periods at infrequent intervals, a certain degree of saturation is permissible.

This second case is the one usually met in practice. The beginner or the one who designs auxiliary poles from rule-of-thumb methods usually supplies coils having an ample number of turns. The usual conception, however, is that the flux which is to be supplied by the auxiliary poles is an almost negligible quantity. Indeed, many designers will recollect that time in their own experience when they thought that a wooden pole would be satisfactory. It comes as a distinct shock of surprise, to learn that the poles are to carry a flux of considerable magnitude.

The minimum pole area permissible, is given by the formula:

$$A_p = A_f \times \frac{B_f\left(1+\frac{L}{100}\right)}{B_p}$$

where A_p = Area cross-section of the pole.
A_f = Area pole-tip.
B_f = Magnetic density in air.
B_p = Maximum magnetic density permissible in pole-core.
L = Per cent leakage.

Air-gap. This should be the minimum permissible from mechanical considerations.

Number of turns in auxiliary coil. The magnetic resistance of the auxiliary pole circuit can be calculated by the same formulas as used for any magnetic circuit. In view of the fact that the iron sections are unsaturated, it will be sufficient to calculate the magnetic resistance or the ampere-turns for the gap alone.

The total ampere-turns in the auxiliary coil is the sum of the ampere-turns thus calculated and the armature ampere-turns.

Example. The above will be simplified by the help of a single example:

Auxiliary coils and poles are wanted for a direct current machine 300 kw. 500 volts 750 rev. per min. 4-pole.

Armature diameter	30 in.
" length	12 in.
Commutator diameter	20 in.
Number of slots	56
Number of commutator bars	224
Thickness brush	¾ in.
Multiple winding	
Volts per bar self-induction	3

The machine must carry 100 per cent overload sparklessly.

From this data the following results can be obtained:

Peripheral speed armature 1180 inches per second.

Number of magnetic lines to be cut per second.

$$\frac{3 \times 10^8}{1180} = 2.54 \times 10^5$$

If length pole-face tip = length armature = 12 in.

$$\text{Flux density per square in.} = \frac{2.54 \times 10^5}{12} = 21{,}200.$$

If the air-gap employed has a corrected length of $\frac{1}{8}$ in.
Ampere turns $= 21200 \times \frac{1}{8} \times 1/3.2 = 830$
Armature ampere-turns per pole =

$$\frac{600}{4} \times 224 \times \frac{1}{4} = 8400$$

Total ampere-turns auxiliary-coil

$$8400 + 830 = 9230$$

Number turns auxiliary coil

$$\frac{9230}{600} = 15.4$$

$$\text{Tooth pitch} = \frac{30 \times 3.14}{56} = 1.68$$

Commutator pitch reduced to armature diameter =

$$\frac{30 \times 3.14}{224} = .42$$

Thickness brush reduced to armature diameter

$$\frac{3}{4} \times \frac{30}{20} = 1.125$$

Minimum width pole-tip $= 1.125 + 1.68 - .42 = 2.385$

Adopt width $= 2\frac{1}{2}$ in.

If the leakage is 25 per cent and if a maximum permissible pole flux density of 100,000 lines per sq. in. is assumed at 100 per cent overload, or 50,000 lines per sq. in. at full load, the full-load density not including leakage is 40,000 lines per sq. in. Assuming the axial length of pole the same as the pole-tip = 12 in.

$$\text{Minimum thickness pole} = 2\tfrac{1}{2}\ \text{in.} \times \frac{21200}{40000} = 1.32\ \text{in.}$$

Adopt thickness pole-core $1\frac{3}{8}$ in.

It will be noted that in this case the auxiliary-pole ampere-turns exceed the armature ampere-turns by about 10 per cent. In most cases this figure varies from about 8 per cent to about 20 per cent.

The advantage of machine with long armatures will also be noted. For a given voltage of self-induction, the longer the armature, the longer is it possible to make the pole-tip, the lower will be the air-gap density and the less will be the number of turns on the auxiliary-coil.

TESTING OF THE AUXILIARY POLES.

The principle upon which this paper has been developed is, that the auxiliary-pole prevents sparking by annulling that part of the armature flux which passes through the commutated coils. The method of calculating this flux as outlined is original with the author.

The method of testing these poles and adjusting for their correct strength follows as a direct conclusion of this principle. It also is original with the author, and is presented here for the first time. Its simplicity makes it a matter of great importance to the designing engineer.

For adjusting the coils, it is not satisfactory to depend on the visual method of adjusting; that is, adjusting the coils till there is no sparking apparent to the eye. Such a method is not accurate, and if there are no facilities available for testing at full load, it gives no indication within wide limits of how the poles must be adjusted at a low load. Moreover, it gives no idea of the magnet curve.

Whatever method of testing for the adjustment is used, it should satisfy the following requirements:

1. It should be an exact method and not approximate.
2. It should be to a certain extent quantitative.
3. It should be a method which is easily understood by shop men and road men.
4. It should employ instruments easily obtainable by both the above classes of men.
5. If the poles or coils must be changed, it should give precise information on the changes that must be made.
6. It should be definite in its indication of trouble. Sparking in a high-speed machine is due to a number of causes. A slight roughness of the commutator, often the roughness caused by the slight unavoidable sparking necessarily incurred in adjusting the coils, will make the visual method useless. Dirt on a brush or want of uniformity of the carbon, vibration of the commutator or brush gear, sticking of a brush in a holder, are all among the causes of poor commutation.

A proper method of testing for adjustment of the coils should not allow its indication to be affected by any of these causes.

A method of testing which the author has found extremely satisfactory, is one depending on the principle pointed out in the first part of the paper; namely, to adjust the auxiliary coils until the volts per bar under the brush are zero. In any particular case, in the absence of facilities for making full-load tests, it will be a sufficient test to adjust the auxiliary coils at the maximum current attainable, until the voltage between two points on the commutator under the brush, as obtained by two voltmeter points resting on the commutator, a bar's thickness apart, registers zero. It is immaterial whether the machine is tested as motor or generator, at full voltage or at low voltage, at full speed or at low speed. It is, of course, assumed in the above, that the results of calculation and of experiments with other similar machines make it certain that the cross-section of the auxiliary pole is ample to carry the flux of armature self-induction at the extreme overloads to which it will be subjected.

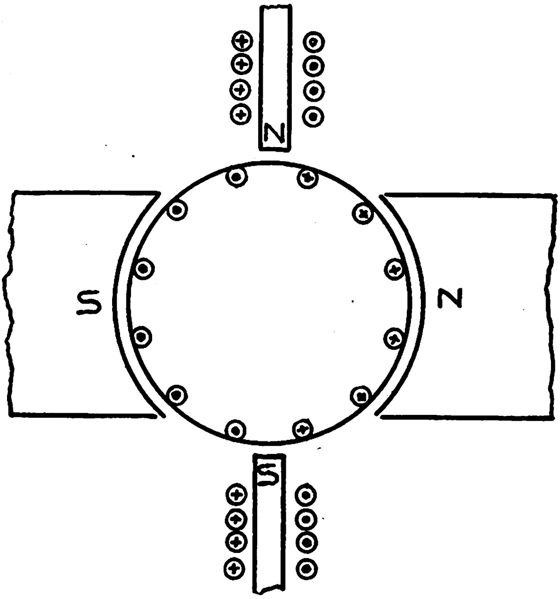

FIG. 8

A brief consideration of the relative arrangement of the polarity of auxiliary and main poles will explain more fully the adjustment necessary to attain the above results.

Figure 8 shows the arrangement of main and auxiliary poles for a generator with clockwise rotation, or for a motor with counter-clockwise rotation. As an aid to the memory this might be stated as follows:

In an ordinary generator on load, the brushes must be shifted forward in order to be brought under the neutralizing pole-tip. The auxiliary poles shift a portion of the forward pole backward, and bring the neutral point to the brush.

The following very simple rule follows from a consideration of these facts:

If in a generator under test, the voltage of a bar under the trailing half of the positive brush, is higher than the voltage of the preceding bar, the pole is too weak, and more current is needed in the auxiliary coil.

If the voltage of this bar is lower than that of the preceding bar, it indicates that the pole is too strong; that is, that the field of the forward pole has been shifted back into the commutating zone.

When the two bars have the same voltage, that is when the volts per bar is zero, the pole is of the correct strength.

Measurements can be made with a direct-current voltmeter with a maximum reading of 3 to 5 volts. It should be noted that this voltage should be measured under the center of the brush, or between bars equi-distant from the center. If the voltage is measured between bars on the same side of the center, or if on opposite sides at unequal distances from the center, a correction must be introduced to allow for the *Ir* drop due to the fact that current is collected equally from all bars and therefore each coil carries current. For measuring this voltage an alternating current voltmeter must not be used as it measures the root mean square of this fluctuating *Ir* drop instead of the average.

This method also provides a test for the correct shape of the auxiliary pole-tip and the proportion of the air-gap at various points. According to the author's experience, a different value in the voltage between bars under the various parts of the brushes, usually accompanies a high density in the body of the pole.

As an example of the accuracy of this method of adjusting a high capacity machine at low currents, the author might mention a machine adjusted by him, for no-volts per bar, under a load of 200 amperes. With the same adjustment, the machine was able to carry 10,000 amperes very satisfactorily.

The method of adjusting as described above, can be relied upon only when it is certain that the pole is of sufficient size to carry the maximum flux of armature induction without approaching saturation. If there is any danger of saturation under maximum load conditions, a saturation curve of the auxiliary pole is desirable and is usually necessary. Such a curve can be obtained by a slight elaboration of this test.

As previously pointed out, with zero volts per bar under the brush, the auxiliary pole flux is exactly equal to the armature flux. The armature flux varies directly as the armature current. Therefore, if a series of readings are taken of armature current, and the corresponding auxiliary pole current necessary for zero volts per bar, a curve plotted from these readings is the saturation curve of the auxiliary pole. Such a curve is of great value for checking original calculations, and of particular value when it is necessary to supply new coils or poles, or both. It shows the exact point at which even a slight degree of saturation is apparent, and therefore the correct size of the new poles; and the exact number of turns necessary on the coils at low loads, and therefore, on the new coils at all loads.

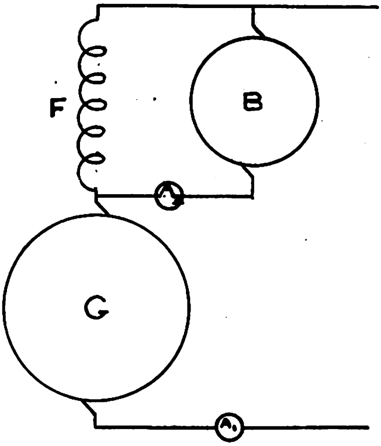

Fig. 9

It will be noted that this method of adjustment depends only on the current carried by the armature, and not in any way on what may be termed the stability factor, or the ratio of the armature ampere-turns to the main field ampere-turns.

That the stability factor is a matter of negligible if of any importance, may be proved by the following experiment. The coils may be adjusted for all loads at full voltage; again, for the same current loads at three-quarter voltage, half, and quarter voltage, and again with armature short-circuited. For the same current the auxiliary coil adjustment for zero volts per bar is identical at all voltages, and the same adjustment corresponds to perfect commutation.

If the stability factor were a matter of importance the recent development for the control of hoist motors and rolling-mill motors known as the Ilgner system would be an impossibility.

A simple method of taking this saturation curve is shown in Fig. 9. *G* and *F* represent the armature and the auxiliary field of the machine under test. *B* is a low-voltage separately excited booster, connected directly across the auxiliary field of the machine. A_1 and A_2 are ammeters, A_2 may be a zero center ammeter, but since not more than one reversal of current is made, this is not necessary.

The method of testing is apparent from inspection. The rising curve should be taken; that is, the pole should be adjusted for increasing loads. It will be found that for the lowest load taken, an accurate adjustment to zero volts is desirable. For succeeding loads the exact curve can be determined by interpolation from a series of more or less exact readings. A slight experience makes it possible to take the saturation curve of the auxiliary pole with very little less trouble than is experienced in taking the same curve for the main poles.

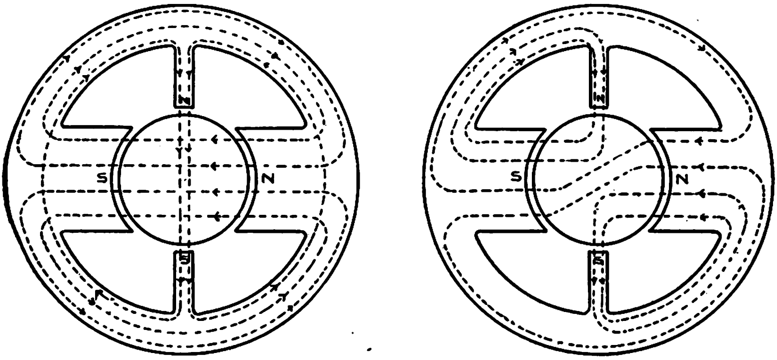

Fig. 10

In General.

A few minor points in connection with the design of auxiliary poles are of interest, although not touched on in the main body of this paper. The shape of the pole-tip which the writer has found as useful as any other, is a tip with a perfectly plane face, designed to help support the auxiliary coil, the edges shaped to reduce magnetic leakage as much as possible. It may be a solid bar of soft steel, as heating of the face from eddy currents does not seem a common source of trouble.

A low magnetic density in the magnetic yoke should be employed, but the importance of this point can be easily overestimated. In the majority of direct current machines, the density in the yoke is low, and the addition of the slight flux of the auxiliary pole will cause very little change in the necessary magnetomotive force. Moreover, the combination of the auxiliary pole flux and the main pole flux in the yoke, is such as to still further minimize this effect of density in the magnetic yoke.

This may be seen in Fig. 10, which shows the flux of the main poles and of the auxiliary poles, both separately and in combination. It will be seen that instead of increasing the magnetic density, from one auxiliary pole to the next, the density is increased only from the auxiliary pole to the edge of the next succeeding main pole, and is decreased by the same amount for the same distance through the rest of the path, so that the necessary magnetomotive force is very little changed.

For a shunt to the auxiliary coil, an inductive resistance should be used, having the same time constant as the coils; otherwise the operation will be unsatisfactory on variable loads.

CONCLUSION.

Poor commutation in a direct current machine, is due to the fact that the coils undergoing commutation are in a magnetic field.

According to this paper, this field is the field of armature magnetization which is identical with armature self-induction. The fundamental principle presented is, that if this field can be annulled so that the current can be collected according to Ohm's law the commutation will be perfect. It follows that the flux to be supplied by the auxiliary pole can be calculated by the use of formulas in everyday use by every designer.

To observe by test if this flux has been annulled, it will suffice to measure the voltage between points on the commutator under the brush, with a low-reading direct-current voltmeter. If a zero reading results from this measurement the armature flux has been annulled, and if mechanical conditions are correct, commutation will be perfect.

A paper to be presented at the 26th annual convention of the American Institute of Electrical Engineers, Frontenac, N. Y., June 28, 1909.

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OUTPUT AND REGULATION IN LONG-DISTANCE LINES*

BY PERCY H. THOMAS

The limitations of the power transmission line as to distance, power, and voltage, and its characteristics as to voltage-variation and energy-loss, have always excited a great deal of interest in the electrical art. The subject has been treated by a number of prominent engineers in its various phases, notable among these being Scott, Perrine, Steinmetz, and Mershon. These men and others have done pioneer work and have outlined the general limiting conditions of transmission. There are some of the relations and peculiarities of the long line, however, that are of importance and interest which have not, to the writer's knowledge, been clearly presented before electrical engineers. It is the object of the present paper to discuss some of these features, more especially the line-output, regulation or voltage-variation, and the line energy-loss.

In view of the uniform distribution of the resistance, inductance, and capacity in a transmission line, a proper study of the long line cannot be made without a suitable formula or equation for calculating the true effect of such a line on the electric current transmitted. As far as the author is aware, no such formula having a form sufficiently simple for convenient use and applicable to the ordinary transmission calculation has been offered. In the paper entitled "Electrical Calculation of the High-Tension Line," such a formula is derived, and is recommended for numerical computations in practical work where accurate results are desired.

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* It is intended that this paper shall be taken in connection with a companion paper presented at the same time and entitled, "Electrical Calculation of the High-Tension Line."

In the analysis of the effects of the transmission of energy through the line which is to be given, reliance has been placed upon the "wave" formula, as it is here called, though check calculations have frequently been made from an approximate formula based on the usual assumption in transmission calculations—that the capacity of the lines is concentrated at the ends. This second formula, while based on approximate assumptions, is of very convenient form. It is called the "split capacity" formula, and is found in the companion paper.

With this introduction, the basis of the following discussion will be clear. While the principles stated apply in the main to lines of all sorts, they are of numerical importance and of special interest chiefly in the longer and relatively high power lines. The determination of their bearing on practical transmission must await the further development of the art.

Electrical action in the line. The critical electrical feature of a transmission system is the action of the line itself. In the passing of energy over a line there is, first, the loss of energy in practical overhead work represented only by the resistance losses. But with power passing over a line at high voltage, a certain amount of leading energy flows to charge the line capacity. This energy in its travel causes a tendency for the potential to rise along the line in the direction of the flow of the leading energy. Similarly there flows to the line a quantity of lagging energy, in virtue of the inductance of the line and the flow of current therein. This lagging energy tends to cause a drop of potential in the line in the direction of its flow. The resultant effect is the difference of the leading and lagging energy-flow, superimposed, of course, upon the true power transmitted and the resistance-drop.

This use of the terms "leading energy" and "lagging energy" is a little unusual; it is adopted only in the absence of a more suitable term for this situation. By "leading energy" is meant that flow of energy which is absorbed by the line capacity on rising voltage and is returned on falling voltage. By "lagging energy", is meant that energy which is absorbed by the line inductance on rising current and returned on falling current.

When the lagging energy predominates cver the leading energy, the tendency is for a drop in potential along the line in the direction of the lagging flow—the well known inductive drop, which is combined with the ohmic drop.

When the leading energy predominates there is a tendency for a rise of potential in the direction of the leading energy-flow, which must be combined with the ohmic drop as before. The rise of potential effect of the leading energy will be opposed to the ohmic drop when the transmission of power and the flow of leading energy are in the same direction. If they flow in opposite directions in the line their effects will, however, be in the same sense.

Now consider the case when the leading and the lagging energies are equal and when they are opposite in phase; that is, when the load power-factor = 1. In this case there will evidently be no appearance in the line of demand on the generator for either lagging or leading energy, and no tendency either for a rise or a drop of voltage therefrom, and the ohmic drop is the only loss of voltage. This condition will be actually realized in practice if the leading and lagging energies of the line are equal and with a load of unity power-factor. If, however, the load current has a lag or a lead, the leading and lagging energies, while they may be equal, will not be opposite in phase and will not neutralize each other. The rather remarkable conclusion follows—that in this case of complete neutralization the loss of voltage is only the ohmic drop and is independent of frequency and is of the same value as with direct current. Thus if this condition can be realized, and there enters no secondary effect, there will be no further economy in direct-current transmission as far as energy-loss or voltage line-drop is concerned, the same effective line voltage being used. But the difficulty is that this condition of equality of the leading and the lagging energy in the line is usually not met with in practical transmissions of relatively short length, and often cannot be economically obtained.

The unfortunate condition exists that the leading energy, being the condenser energy, is practically constant, whatever the load on the line, since it depends only on the voltage of the line. On the other hand, the lagging energy depends only on the actual amount of power or current being transmitted, since it varies as the square of the line current. Thus with half load or no load, a line that was balanced for full load would have a large excess leading energy flow.

Suppose a line to be laid out so that there is an equality between the leading and the lagging energy at full load. At full load the line-drop in the direction of the power-flow will be the ohmic drop; but at half load the leading energy-flow will greatly predominate, and the actual line-drop in the original direction will be the ohmic drop less the effect of the excess leading energy in tending to produce a rising voltage in this direction. This assumes the leading energy to be supplied in the same direction as the power. Just what the resultant would be depends on the particular constants of the case. Now, when the load becomes zero, the line-drop will become a rise to the extent of the ability of the leading energy to bring about this result, since the ohmic drop will then be zero. Thus the range of delivered voltage from no load to full load will be the sum of the ohmic drop at full load and the leading energy rise at no load, which will in long lines be a very material amount.

In the case assumed suppose, however, that the power is transmitted in one direction while the leading energy is supplied from the other in any suitable manner. Then the full-load drop is the ohmic drop, as before; the no-load drop will be of the same numerical magnitude as before, but in the opposite direction. That is, the no-load drop will tend to make the end from which the true power is furnished the higher in voltage. Now, this is the same direction of potential-slope as the ohmic drop caused in the full-load condition of the line; thus the no-load and full-load cases show the same line voltages at both ends, provided, of course, the ohmic drop is equal numerically to the leading energy-rise at no load.

This relation of full-load and no-load drop may be often quite well approximated. When it is attained, the voltage variation of the line ceases to be a limiting feature of the transmission, and the amount of power that can be carried on a single line depends only on the amount of copper used. The effect of frequency, as already stated, is almost eliminated, within reasonable limits.

The practical problem, then, is to find some satisfactory way by which to realize the ideal adjustment of leading and lagging line energy, and also the approximate equality. of the leading rise of voltage at no load with the ohmic drop of voltage at full load in any particular case.

It should be carefully borne in mind that the leading and lagging energy and energy-loss so far discussed are wholly confined to the line and have no necessary relation to the leading or lagging current in the load.

The factors by which the relative values of the leading and the lagging energy of the line are controlled are; the line voltage, the actual load or current, and the ratio of the line inductance and capacity per unit length. The energy taken by the capacity of the line varies as the square of the line voltage, so that this factor is of extreme importance. The lagging energy of the load varies as the square of the current, as has already been mentioned. Neutralization of the leading and lagging line energies can be obtained only when the power-factor of the load current is unity, for only then the leading and lagging energies are opposite in phase.

The current of the line, of course, decreases directly with the increase of line voltage chosen, if the power transmitted be kept constant.

The energy flowing to the capacity of the line per unit length is proportional to $p\,C\,V^2$, where $p\,C$ is the capacity susceptance and V the voltage. The lagging energy will be proportional to $p\,L\,I^2$, where $p\,L$ is the inductive ohms and I the current. If these are equal then $\frac{V}{I} = \sqrt{\frac{L}{C}}$, which is the condition of balanced out-of-phase energy. It is clear that this can be reached for any line and voltage by properly choosing the current, and for any current by properly choosing the voltage. It is also clear that the condition is independent of frequency.

Equation (34) of the companion paper gives the line voltage equation when $R = 0$. Here if the current or voltage is chosen to fulfil the above condition, the generator voltage $= S \sin (p\,t + \theta + x\sqrt{p^2\,C\,L})$, showing that the voltage of the line is constant as it should be. The resistance is chosen as zero, as otherwise the change of voltage along the line will destroy the exact balance of the leading and the lagging energy.

Thus as the net result, the ratio of the leading to the lagging energy varies as the fourth power of the voltage when the power transmitted remains the same. The capacity of the line can be increased by adding condensers in parallel across the line at regular and sufficiently frequent intervals; the inductance can similarly be increased by the addition of choke-coils in the same manner. But these expedients have never found much favor. As the power and voltage are often fixed by other considerations, some other method of altering this ratio than change power or voltage would be desirable.

The following method is suggested for consideration in favorable cases. The several line conductors may be divided into two, three, or more wires, which are separated somewhat from one another but mounted on the same insulator or adjacent insulators, the current dividing between them. The effect of this arrangement will be to increase the line capacity and to decrease the line inductance, both of which changes tend to alter the ratio of capacity to inductance in the same direction. With large power and long-distance lines, this increase of ratio is found in many cases to be in a favorable direction. This plan will be further discussed at a later point of this paper. Formulas for numerical calculations will be found in the companion paper.

It should be said that in this matter of adjustment of the leading and lagging line energies, a change of frequency is of no avail, since both elements, capacity and inductance, are affected in the same manner. Furthermore, while a certain voltage may be most favorable in some particular case for balancing the line effects and reducing the line-drop to the ohmic equivalent, it does not necessarily follow that this voltage will give the best transmission condition; for the advantage of a higher voltage may easily more than offset the favorable adjustment of the leading and lagging energy of the line. Furthermore, the most favorable line conditions will not always be the most favorable for other parts of the system, and any complete design will be a compromise, as usual.

Instead of feeding leading and lagging current from one end of the line or the other, it may be fed from both. In this case the result will be the resultant of the various tendencies already explained.

It is clear that the end from which the leading or lagging current is fed determines the direction in which the rise or fall of potential will be found. In other words, the same current that is leading, considering the direction from power house to the receiving end, will be lagging if taken in the other direction. A leading current fed into the line from the generator end tends to cause a higher potential at the receiving end, while the same current fed from the receiving end tends to cause a higher potential at the power-house end.

If the leading current be fed equally from both ends, the potential will tend to rise toward the middle and fall toward both ends of the line. Similarly with lagging currents. If the currents fed from the two ends are not equal, the point of maximum potential will be thrown in one direction or the other, toward the end into which the smaller current flows. Thus in the control of the potential of a line, it may be advantageous to supply the leading current from the receiving end or from both ends, as will be pointed out later.

If the so-called synchronous form of generator be used there would be no difficulty in supplying the necessary amount of power and lagging or leading current to the line, as may be required in any case, but if either lagging or leading energy be demanded at the same time as useful power, the capacity of the generator must be greater in inverse proportion to the power-factor. This is well known.

If the lagging or leading energy be supplied from the receiving end of the line, it may be supplied either by additional generators at this point or by synchronous motors or converters. One disadvantage of this arrangement is the difficulty of making the two generators at the opposite ends of the line divide the line current between them in the desired ratio, or of making the generator or the synchronous motor or converter at the receiving end supply all the leading current to the line to the exclusion of the power generator. Of course there would be no difficulty in making the power-house generator supply all the useful power, as this function is determined by the governor of the prime mover.

Where it is desired to supply the leading current to the line from the receiving end, the expedient is suggested of using non-synchronous generators at the power-house end, and synchronous motors or auxiliary generators at the receiving end. In this case the non-synchronous machines while generating the amount of power for which their governors may be set, will take only a certain definite amount of magnetizing current; that is, current suitable to supply leading energy to the line from the power-house end. The no-load leading current, except for the magnetizing current of the non-synchronous machines, will then be supplied from the synchronous machines at the receiving end, as is desired. The use of synchronous motors driven from non-synchronous generators has been fully discussed by Waters in the Institute TRANSACTIONS.* This use of non-synchronous machines will be again discussed later in this paper.

But the load as well as the line must be considered. Unfortunately, the load has its own particular characteristics, independently of the other parts of the system. Its power-factor is not determined by the line current or the line conditions. It must take a certain current, usually lagging, and its requirements will vary as the load changes. Thus other conditions must be suited to the load conditions. But the line, when adjusted for best internal conditions of balanced leading and lagging energy, will deliver current without lag to the load, which is not usually suitable. In case the line conditions are not to be wholly sacrificed to the load condition—this is usually the case in most transmissions of moderate size—it is necessary to supply the load lagging current by synchronous apparatus, either motors or generators. Such an arrangement is perfectly feasible, though not often used at the present time. In case such synchronous apparatus at the load end has been already determined upon to supply leading current to the line, as already explained, these same machines may serve both functions. It is to be noticed that the lagging current of the load and the leading energy supplied by the synchronous machines into the line from the receiving end tend to neutralize each other; and that if a leading current enter the line from the receiving end equal to the lagging current of the load these will balance each other and there will be no current taken from the synchronous machine.

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* A.I.E.E. TRANS. Vol. XXVII, 1908, p. 157.

A compromise may be effected between the best line condition, requiring the delivery from the line of current at unity power-factor and the best condition from the point of view of the synchronous machine in which the load lagging current at full load should be supplied wholly from the leading line current.

In the main the electrical action of the line has now been briefly outlined. The most notable features are:

1. That by properly balancing the leading or capacity energy and the lagging or inductive energy in the *line itself*, the full-load transmission will be as though the line had only ohmic resistance.

2. That a reasonable constancy of voltage conditions on the line *for all loads* may be obtained by supplying the leading energy in the condition when the load is off or light, partly or wholly from the receiving end.

In actual cases of transmission it is usually found that the lagging component so far overshadows the leading component as to render the former the dominating feature. In this case the only expedient for controlling line-drop would seem to be to raise the voltage or to limit the maximum load. It will be possible, however, in such cases to apply the suggestion made above—to divide the conductor to reduce the line inductance and increase its capacity. In the case of large excess lagging current, the loss of capacity and good regulation in the generator due to the lagging component of the load added to that of the line is well understood. The lagging component of the load can be balanced by synchronous machines at the load end, but this adds too much complication for most plants, or at least seems to be so considered. Where such synchronous machines are not used at the receiving end, a large line capacity current may be desirable to balance the load lagging current.

But it is not the purpose of the present discussion to consider the smaller plants as distinguished from the large long-distance systems in which it is feasible to balance the leading and lagging line energy.

There is a remarkable effectiveness of the arrangements here suggested in rendering practicable, electrically speaking, the transmission of large amounts of power in a single line for long distances with an acceptable voltage regulation. This can best be shown by means of a few actual examples. The first case assumed (case *a* Table A) has been taken to represent the transmission distance of the well known Victoria Falls transmission, but all attempts to parallel the other commercial or engineering conditions of this project have been carefully avoided.

The transmission is taken as having 700 miles of three conductors spaced 12 ft. apart and each having three times the section of No. 0000 wire. The frequency is taken as 25 cycles. Assume at the start that the power to be delivered at full load is 40,000 kw. at 150,000 volts and with a load power-factor of 0.85. Assuming that synchronous machines at the receiving end supply all of the load lagging current except enough to charge 300 miles of the line—giving a line power-factor of 0.918 at the receiving end—the drop in voltage will be 12.1 per cent and the generator power-factor will be 0.96, leading. The true energy-loss in the line will be 10.4 per cent., giving what seems to be at first not an unfavorable condition. The effect of throwing off the load (case *b* Table A), however, is to cause a rise in voltage of about 22 per cent, assuming that the synchronous machines at the load end supply no leading energy in the no-load condition or that they have dropped off the line. This gives too great a range of voltage at the receiving end for satisfactory direct operation, TABLE A.

ILLUSTRATIVE LINE ADJUSTMENTS WITH CALCULATIONS.

	Distance in miles	Size of conductors	Spacing of conductors in feet	Transmitted power, three phase	Line voltage delivered	Line current load end, "–" means leading	Frequency	Line power-factor	Voltage drop in % of generation voltage	Line energy loss in % gen. power	Line power-factor generator end "–" means leading	Line current generator end, "–" means leading	$\frac{p x}{v}\left(\frac{360}{2 \pi}\right)$
a	700	3 #0000	21	40,000	150,000	145.3	25	0.918	12.1	10.4	–0.963	134.8	34° 48′
b	"	"	"	0	"	0	"	—	–22.4	—	—	—	"
c	"	"	"	60,000	"	200	"	1.00	11.5	13.8	–0.994	206.8	"
d	"	"	"	0	"	–63.8	"	0	–.2	—	—	—	"
e	"	"	"	60,000	"	202	60	0.99	7.2	13.2	–0.974	219.7	83° 6′
f	"	"	"	67,500	"	225	25	1.00	15.7	15.3	1.000	224	34° 48′
g	"	"	D* "	60,000	"	235	25	0.85	15.7	11.7	–0.96	199	35° 6′
h	"	(3½) × #0000	D* "	75,000	"	278	"	0.90	19.6	13.7	–0.988	237†	"
i	"	"	*D** "	50,000	"	231.6	"	0.72	17.5	11.5	–0.962	161.4‡	"
j	"	"	*D** "	0	"	–175	"	0	10.4	2% 75,000 kw	–0.09	–53.3	"
k	300	3 #0000	"	60,000	"	235	"	0.85	17.1	7.8	0.876	205	Sp't Cap.
l	"	"	D* "	"	"	"	"	"	11.4	7.3	0.971	196.6	Sp't Cap.
m	"	(⅔)² × #0000	10.5	12,000	100,000	75	60	0.80	6.23	4.46	0.873	67.5	35° 36′
n	"	"	"	20,000	"	125	"	"	20.2	7.00	0.998	86.1	"
o	"	"	D* "	50,000	"	250	"	1.00	14.5	14.8	1.000	250.7	35° 48′

D* means divided conductor, each line wire divided into three separate conductors spaced 18" apart. Inductance reduced to from 0.60 to 0.59 of normal.

† Leading component of line current at generator end = 36.5.

‡ Leading component of line current at generator end = 44.2, compare 53.3 amperes in case *j*.

but probably would be satisfactory for the regeneration of the power.

In this case it is evident that the leading energy in the line greatly overbalances the lagging energy in the line taken as a whole, but that at the load end the lagging component of the *load* causes a predominance of lagging at this end of the line, which is gradually overcome by the leading excess in the line until at the generator the leading energy predominates. This is in a way a favorable combination, for the load might easily be supplied with lagging current without the intervention of synchronous machines at the load, and yet the general excess of leading energy in the line tends to limit the line drop. The weak point of this arrangement is the rise in line voltage from generator to load on no load or light load, and the increased line energy-loss.

To balance the line leading and lagging energy components at full load, we may increase the total power transmitted making it 60,000 kw. delivered (case *c* Table A). In this case to obtain unity power-factor at the load it may be assumed that there are synchronous generators to carry the load lagging current, as distinguished from the lagging line energy. The line drop will then be 11.5 per cent and the generator power-factor 0.994 leading, showing that the line leading and lagging energies are about equal. In this case the line current is approximately the same all the way through the circuit, and the line energy-loss calculated by the wave formula is 13.8 per cent, almost exactly the product of the resistance and the square of the delivered current, as it must be. The line drop is a little less than the product of the resistance and load current in this full-load condition, on account of the slight excess of the leading energy in the line.

Now if it be assumed that the leading current for the no-load condition be supplied from the load end, then the rise in voltage backward along the line from the load end to the generator end will be 22 per cent (see case *b* Table A). This is the same thing as a drop of the same amount in the direction of the power transmission, and the net change in line voltage from full load to no load, and is only 10.5 per cent and this occurs at the power house, provided the voltage of the synchronous apparatus at the load end, which does the magnetizing, is kept constant by some regulator or other means. Thus this condition is a highly satisfactory one for the transmission, provided no indirect disadvantages appear.

If, on the other hand, enough charging current—about 64 amperes—be fed from the receiving end to charge about 300 miles of line, the rest being supplied from the power-house end, the no-load voltage at the power-house end will be 0.2 per cent higher than the receiving end, showing the effect of feeding leading current from both ends (see case *d* Table A). The potential at the middle of the line, however, will be somewhat higher than at either end.

In the case just assumed the synchronous machines must carry the whole lagging component of the load at full load and leading energy for the line at no load.

But it is possible to improve the practical conditions a little by allowing a certain portion of the load lagging current to be carried by the line capacity, as the leading and lagging components are at right angles to the power component and produce little effect in the line as long as they are relatively small. Line charging current flowing from the line out to the load is there actually seen as lagging current. As far as carrying the lagging component of the load is concerned, the work to be done by the synchronous machines will be reduced by this expedient, thus permitting a larger power output for a peak load, though the no-load condition will be unchanged.

To accomplish this result, it will be necessary to increase the line capacity energy or to decrease the load. If the former alternative be chosen and the expedient suggested above of dividing the line conductors be used, assuming three conductors, each equal to one No. 0000 wire with the same average spacing but separated individually 18 in., the line inductance and capacity will each be altered in approximately the ratio 0.6. The line conditions will then be such as to give a drop of 15.7 per cent (see case *g*, Table A) taking the power-factor as 0.85 at the load on at full load. This will give a power-factor at the generator of 0.96 leading. The drop has been thus increased as the lagging excess at the receiving end of the line dominates the leading excess at the power-house end. Here as far as the line itself is concerned, the leading energy far exceeds the lagging energy, with the consequent wide variation of current and power-factor through the length of the line. The lagging load component of the load entering the line at the load end is sufficient to dominate the line near this point, though the excess of leading energy in the line soon overpowers the lagging and leaves the generator current leading by a considerable factor.

These line conditions while not the best for the line itself--the drop has increased to 15.7 per cent—is in some ways better than case *c*, on the whole, as there is no call on the synchronous apparatus at the load end at the full-load condition, and this apparatus is available as an auxiliary for supplementary power to carry peak loads. But it is evident that the leading component of the line is unnecessarily large, and a larger amount of power would more nearly balance the leading and lagging energies. Thus, assuming that the power be increased to 75,000 kw. and the power-factor at the load end be made 0.90 and that at the same time the section of the conductor be increased 25 per cent to keep down the true line energy loss, then the line-drop will be 19.6 per cent (see case *h*, Table A) and the generator power-factor will be 0.988 leading. The line loss is then reduced to 13.7 per cent. This is a favorable condition, for the energy loss is low, the synchronous apparatus is called on only for a relatively small amount of lagging current at full load, assuming that the *load* power factor is as before 0.85, and at no load the synchronous apparatus is free to supply the leading energy to the line. On no load the rise in voltage toward the generator will be 10.4 per cent (see case *j*, table I), assuming 175 amperes charging current at the load end, which gives a net change at the power house of some 9 per cent, which is entirely satisfactory. This assumes constant voltage maintained at the load end by the synchronous machines.

Thus it is seen that by the principles here expounded, it was possible practically to double the output of this line over that obtained by the ordinary method of operation. This double output was obtained with a very much more satisfactory voltage regulation, and with a true energy loss that could be reduced to any desired value by the mere addition of copper.

It is interesting to note that the cost of copper per kilowatt, in the line with 75000 kw. transmitted and copper at 16c. is about $56, by no means a prohibitive value.

Similar examples might be worked out for higher frequencies, where these are desired, and though the service will be much more sensitive to the accuracy of proportioning, there is no theoretical reason why nearly as good regulation should not be gotten with 60 cycles as with 25.

Case *c*, Table A, above, taken for 60 cycles would give the results shown in case *e*, Table A. Here a slightly lower load power-factor has been chosen, since the leading energy is slightly in excess. The results are very nearly the same for both frequencies, the drop being less with 60 cycles on account of the greater excess of leading current at the power house.

To show a more exact balance between the leading and lagging energy than is shown in case *c*, case *f* has been calculated for the same line with a somewhat larger load, 67,500 kw. The power-factor is here found to be unity at both ends of the line, the current the same within less than one half per cent, and the energy-loss nearly equal to the drop in per cent. The drop calculated as the product of the resistance and the current = 15.2 per cent for this case which should be compared with the value by wave formula of 15.7.

The results cannot be in perfect accord, however, for in view of the drop in the line, the leading and lagging energy cannot be exactly balanced at all points. The leading energy varies from point to point, while the lagging energy is substantially constant. The leading and lagging energy are here equal at the center of the line.

Another example will illustrate a 60-cycle line. Assume a 300-mile transmission, with conductors of a diameter $\frac{3}{2}$ that of No. 0000 wire, spaced 10.5 ft. With a delivered voltage of 100,000 volts and load power-factor of 0.80 and delivered power of 12,000 kw. three phase, the drop at 60 cycles will be 6.2 per cent and the true loss 4.5 per cent (see *m*, Table A). The power-factor of the generator is 0.87 leading. Here the leading energy greatly predominates and the heavy lagging load current is changed into a leading current at the generator. The drop is satisfactory but the power transmitted is small. If the power is increased to 20,000 kw. the drop becomes 20.2 per cent, which is excessive although the line energy loss is small (see *n*, Table A). The generator power-factor becomes 0.998.

Again in this case the leading energy predominates. The drop would here be improved if there were synchronous machines at the lowering end of the line to carry the lagging current of the load.

If, however, the divided conductor arrangement be used—three parts for each conductor spaced 18 in. apart—the inductance and capacity will each be changed in the ratio 0.59 (see formula in companion paper). Choosing now a power delivered such as to balance the leading and lagging energy at the center of the line, that is 50,000 kw., the drop will be 14.5 per cent and the generator power-factor unity as well as the load power-factor (see case *o*, Table A). The line-loss is 14.8 per cent and the load current of 250 amperes becomes 250.7 at the generator. This is another excellent example of the effect of a close equality between leading and lagging energy.

The cost of line copper per kilowatt in this case with copper at 16c. is about $22, a reasonably small value.

In this connection it is interesting to compare the transmission curves given by Mershon in a paper before the Institute.* Here Mershon studies the economical conditions of power transmission as indicating the commercially feasible limits of distance. Mershon has tacitly assumed that the effect of the alternating character of the current on regulation can be ignored in his discussion by taking the line-drops as the product of the resistance by the current. Such an assumption will ordinarily be unjustifiable, for with the usual spacing of conductors the line-drop will be far from these ohmic values. With the actual values shown by Mershon's curves, however, the relations are such that for the long distances the leading and lagging energies are not very far apart. For example, the case *c*, Table A comes very closely to his curves. In other cases, however, especially the short distances, the lagging energy will greatly predominate, giving much larger line drops than those shown in Mershon's curves. It should be said, however, that in these cases the drop is relatively small on account of the short distances.

Mershon states that he uses synchronous machines to bring his average line power-factor to unity. What he does is to reduce by this means the power-factor of the energy at the center or some other point of the line to unity, for this is the only power that the synchronous machine possesses. It cannot balance the leading and lagging energy of the line itself, as distinguished from the leading or lagging current of the load. As already explained, unity power-factor alone does not give the condition which will permit the transmission of power with a purely ohmic line drop, but the equality of leading and lagging energy within the line itself must also be obtained. Now, as has been shown above, this equality can in most cases of important transmissions be approximately obtained, by the proper choice of voltage and power transmitted and of relative line conductor arrangements; and the bad effects of the leading current building up a rise on light loads can be eliminated by supplying the leading energy from the receiving end of the line, so that the Mershon condition of direct-current drop can be quite nearly attained by these expedients. It is a matter for comment that the Mershon curves chosen for reasons of economy come rather near, in the maximum cases, to the best conditions for internal line conditions. This equality is departed from in the shorter distances, however.

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* Maximum Distance to which Power Can be Economically Transmitted, Vol. XXIII, 1904, p. 759.

In the above discussion only the simple direct principles involved have been considered, since in this way they are most clearly pointed out. In most practical transmission systems these simple principles, while still perfectly true, are often dominated by naturally unfavorable proportions or by other features. Even in the long high power lines where the line is the most important feature, many limiting conditions will often be found to prevent the realizing of ideal conditions. For example, the effect of leading current in the fields of synchronous generators is marked, and in the absence of automatic regulation will cause voltage variations. For this work in important cases possibly machines especially designed to hold the voltage constant might be desirable. The difficulty of obtaining the desired division of leading current among a number of stations may be troublesome, especially where the sub-stations are under independent control. Several lines of different lengths radiating from the same power house or those that are cross-connected may be troublesome. But it is the object of the present discussion to point out the principles governing the electrical action of the line, and not to discuss the secondary questions inevitably brought up by applications in special cases.

In calculations of lines in which the leading and lagging line energies are approximately equal, the split-capacity formula should not be used without great caution, for then it naturally has a large error especially in the value of line-drop. That this error will exist is evident from the fact that while in the line itself the effects of capacity and inductance are eliminated, the split-capacity formula shows an entirely different condition. Table I in the companion paper shows a number of cases calculated by both formulas. The close agreement in some instances with the wide divergence in others is notable.

Terminal apparatus. Much depends on the type and adjustment of the terminal apparatus, generators, motors, and synchronous converters, in controlling the line voltage, energy-loss and power-factor.

The object to be attained by the choice of type and method of control of the terminal apparatus, in addition to the generating and delivering of power, is the controlling and minimizing of line-drop and line energy-loss. As already pointed out, the terminal machines may control the line voltage by controlling the amount of charging current fed from the respective ends of the line. This is the same thing as controlling the power-factor at these points; for leading current to the line is the same as lagging current from the line to the apparatus.

It is important to bear in mind that one sort of terminal machines may be desirable when the power-factor adjustments are to be made by hand, another sort when it is desired to make the adjustments as far as possible automatic. The simplest case above was that in which the charging current is largely supplied from the receiving end.

The advantage of the non-synchronous generator at the power house in such a case is evident; for it will automatically throw the charging current; that is, the charging current over and above its own magnetizing current, on the synchronous machines at the load end. Since most large transmission will have a steam auxiliary at the load end, this can to great advantage utilize synchronous type generators and supply the charging current of the line, except for a certain definite portion that will be supplied necessarily by the magnetizing current of the non-synchronous machine at the power-house end. This partial charging current from the power end is of advantage at full load, as it tends to reduce the ohmic drop. If desired, the non-synchronous machine can be made to take a relatively large magnetizing current for this purpose. But for the light load condition, the charging current should be fed largely from the load end, and this is to some extent automatically accomplished by the fact that at low load the non-synchronous machines takes less magnetizing current. But the dominating effect is the setting free at no load of the leading energy that was neutralized by the lagging energy of the line at full load, which causes the desired no-load rise in voltage toward the power house, and which is depended on to match the full-load drop toward the load end.

The use of non-synchronous machines has other advantages than this of allowing a definite automatic distribution of the charging current for the line, prominent among which are a number of mechanical and other advantages discussed in a paper by

Waters.* The non-synchronous machine at the power house gives another advantage, in that any tendency for excessive rise of potential at the power house will cause a greatly increased magnetizing current in the machine; that is, charging current to the line, which will help to keep down the rise of potential, since it will tend to cause a slope of potential along the line in the opposite direction. The limiting of the tremendous amount of short-circuit current that flows from large systems through the well known action of these non-synchronous machines deserves special mention. Again the fact that such machines need not be synchronized may be a very great advantage. While the paralleling of synchronous generators in a normal power house has no great difficulty or drawbacks, the separation of such machines by long distances is a great handicap, and the advantage of the non-synchronous machines here is noteworthy. While this is an operating advantage only, as such it is entitled to the fullest consideration.

Since even with a non-synchronous generator it is necessary to have accurate adjustment in the speed of the machine to avoid a sudden rush of current, and since in any case the throwing in of a large unit is always a disturbing factor, it is suggested that if a non-synchronous generator be used at the power house, load circuit-breakers be omitted, and that the step-up transformers and the generators be treated as a part of the line.

In some ways it is disadvantageous that the magnetizing current for the non-synchronous generator should come from the receiving end, as the power house would consequently be dependent on the distant station for excitation. In normal operation, however, the load will be continuous and there will normally always be magnetizing, current available while for emergencies a synchronous type generator of the necessary capacity to handle one line may be installed at the power house. Such a generator could then be used for local power, if the power-house voltage should be found too variable.

In case *a*, Table A, the generator power-factor is 0.96 leading, which is suitable for a large non-synchronous generator under favorable speed conditions. Thus such a generator, with the assumed synchronous apparatus at the load end, could supply the line under the conditions assumed with the voltage drop and line-loss shown in this case. If the load were thrown off, the voltage would rise toward the power house (as the major portion of the line charging current would be supplied from the synchronous machines at the load end; that is, all but the magnetizing current of the non-synchronous machine) and to an amount not far from the full-load drop.

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* Waters, TRANS. A. I. E. E., Vol. xxviii, p. 157, 1908.

Cases *e* and *g* and *h*, Table A—all have leading line power-factors at the power-house end, which, by a slight increase or decrease, would be suitable for a non-synchronous machine.

In these cases the voltage on no load would be little different, as in case *a*. To show the effect of intermediate loads, case *i*, showing the effect of two-thirds load in case *h*, has been calculated, giving a drop from power house to load end of 17.5 per cent, the lagging current of the non-synchronous machine at the power house being assumed to be slightly reduced.

In many ways the plan of having the system controlled at the receiving end has great operating advantages. This arrangement is simplest with auxiliary prime movers at the receiving end. It is possible, however, to accomplish similar results with synchronous motors.

The natural location for the control of a system, from the point of view of the service, is the receiving end; the custom of control from the power house ordinarily results from the greater complication of the apparatus at this point. If the use of non-synchronous machines should render the transfer of control to the receiving end feasible, this would be a welcome change.

Again it is certainly advantageous to have the voltage controlled at the load end rather than at the generator end of the line. An automatic regulator may be used on the machines at the load end to keep the voltage constant on the receiving bus-bars for practically all load variations. What variations of potential do occur would then be at the power-house, where they would ordinarily be of relatively little consequence.

It may be said in favor of using synchronous type machines at both ends of the line, that they permit much greater flexibility of adjustment of the relative amounts of leading current furnished by each and thus greater flexibility in the line control. The synchronous machines can of course take either a leading or a lagging current at will. The very flexibility of this system is perhaps its weakness, for the attendants at all points must work intelligently and in harmony, while with the non-synchronous machines the control is automatically thrown to the synchronous machine.

In smaller transmissions it will usually not be worth while to use machines of either type at the receiving end, as is shown by present practice, in which case only synchronous type machines can be used at the power house.

General limitations. The limitations of a method of design or operation usually require more careful consideration than its merits, and the more important of the conditions limiting the methods here proposed will be considered. It is a fact, however, that the weighing of advantages and disadvantages is very unsatisfactory in a general case, as the particular conditions of each system are a most important factor.

With such a close adjustment of proportions as is necessary for the most economical results theoretically, departures from the ideal condition may produce relatively large discrepancies. For example, in the full-load condition with leading and lagging energies balanced, overloads will add very rapidly to the drop. Similarly, with a lowering of the power-factor required of the line at the receiving end. With the arrangement utilizing the auxiliary machines at the receiving end and non-synchronous machines at the power house, however, the variation of power-factor will be cared for automatically by the machines at the load end. If the line design be made approximately correct for the worst condition to be met; that is, full load at the lowest power-factor, so that the leading and lagging energies of the line are balanced, and if the drop is then not excessive and the non-synchronous machines or other generators at the power house take their correct amount of current, conditions should be stable.

A tendency to instability is inherent in any system in which the main generators do not assist in maintaining the voltage, such as systems using non-synchronous generators. Synchronous machines are notably at a disadvantage with lagging or leading current in the matter of voltage regulation, as such currents tend to demagnetize or strengthen the fields. If, then, the system is such that a relatively small machine must carry all the leading or lagging current for machines of much larger capacity, the tendency to instability is greatly increased. This will undoubtedly be one of the features requiring most careful consideration in such a system as here proposed. Special designs of synchronous machines would help somewhat. A quick-acting automatic regulator may be used to control voltage variations within reasonable limits in view of the sluggishness of large generator fields.

In the partial load or light load conditions the line-drop will be very sensitive to the relative amount of charging current supplied from the respective ends of the line, a greater portion from the power-house end causing a tendency toward a lessened drop toward the load end. With conditions tending to considerable variations, as they do in a large system, this fact will be a menace of line voltage variations. This again shows the value of automatic or semi-automatic control of the charging current distribution. On the other hand, it is clear that by properly proportioning the relative amounts of charging current supplied from the two ends of the line, an adjustment of the relative full-load and no-load voltage drops can be obtained and the two made equal. This adjustment can be much facilitated with non-synchronous generators by providing non-automatic means for adjusting the amount of lagging current at the power house. Separate adjustable-shunt lagging coils can be provided if desired.

On less than full load, the leading line energy and the lagging line energy no longer being equal, the most favorable conditions for economy of line loss no longer exist, and in the lighter loads the charging current or leading energy in the line materially increases the line energy loss. This condition can be reduced only by feeding charging current from both ends of the line, or even from three or more points along the line. The maximum charging current flowing at any point of the line will then be only that necessary to charge a fractional part of the whole.

In this matter of the added light-load line-energy loss, the divided conductor is at a disadvantage on account of its increased capacity and charging current. Thus in planning the line it is necessary to consider prominently the load at which the system is to run for the major portion of the time.

If the no-load voltage at the ends of an exceptionally long high-frequency line be adjusted to approximate equality by feeding charging current from both ends, and the voltage rise at the middle of the line is excessive, this can be corrected by feeding charging current also at the center of the line either from synchronous or non-synchronous machines or from choke-coils.

Limitations will also be introduced by the layout of the system. A large plant of the type here under discussion would require at least two and probably three transmission lines, and with such large amounts of power as would be necessary to give economical financial conditions, two or three generators would be required for each line. In this case the interchanging of generators and loads between lines, if not carefully planned, might disturb the best adjustments of line and the regulation.

Again, when two separate sub-stations are fed from the same power house, changes of load and of field adjustment in synchronous generators at the two sub-stations would tend to cause overloading of one or the other of these machines and also a certain voltage variation.

Many special cases can be imagined in which will appear limitations and difficulties of varying importance in the use of the principles here discussed. Each case must be judged on its own merits, but the chief difficulties directly introduced have been pointed out.

The ratio of the leading and lagging line energies can be controlled, if desirable, by adding capacity in the form of condensers or synchronous types of machines across the line at sufficiently frequent intervals, or by similarly adding inductance by coils or machines. The coils might be added in series with the line, in which case they will tend to balance the leading energy for one load only, as with the normal line inductance, while with the shunt coils the leading energy is balanced for all loads and all voltages. These coils and condensers must be at sufficiently frequent intervals, the more frequent the more perfect their action. This use of distributed coils or condensers is analogous to the well-known Pupin load coils for telephone circuits.

The method of controlling the ratio of line inductance to line capacity by dividing conductors should receive fuller consideration. The electrical effect of dividing the conductor is not difficult to calculate approximately, and a suitable approximate formula is derived in the companion paper, formulas being given for the two-part and three-part divisions. The maximum practical numerical variation in favorable cases will be a reduction in the inductance and an increase in the capacity by the factor 2, obtained by the use of the three-part division. This gives an actual change in the ratio of capacity to inductance of 4. This is a little greater than will usually be easily realized. More or less serious mechanical difficulties are introduced by this construction, but these are by no means insuperable. It is probable that such an innovation will not be worth while, except in large, long, and important systems with relatively large conductors.

The divided parts of the conductors may be spaced equally and run straight and parallel to the line, or may be arranged spirally. They may be kept at the same spacing from one another at all points, or may be brought together at the insulators for mechanical support. They can be easily spaced by spreaders on the spans.

A certain mechanical reliability is introduced by the multiple conductors, in that if one is broken, through some defect in the wire, for example, the others will hold it up. With suspension-type insulators the supporting of multiple conductors will be mechanically relatively easy.

The wind and ice strains will be materially increased with the split conductors, but this fact will not necessarily be prohibitive: first, when the alternative will be an entirely new line on account of excessive drop, which will be still more expensive; secondly, with large conductors, since in such cases (where this method will be most useful) the wind strain, being relatively small in proportion to the weight and at right angles to the weight, will not add materially to the total, and since the ice strain will also be a much less important relative quantity than with the smaller wires, or may be absent entirely.

With two conductors the exposed area will of course be 1.4 times as great as with the same copper in one conductor. With three conductors the increase of surface will be 1.7.

The element of mechanical handling and stringing with very large conductors may work out in favor of divided conductors. In some cases it may be desirable to support each of the conductors on a separate insulator. This would give a distinct advantage in reliability, for if any one insulator should be shattered or the wire burn off, as in the case of a lightning ground, the others might support and insulate the line. This result, of course, assumes the automatic clearing of the line when the accident happens.

Again, the two or three divided conductors might be carried separately and insulated from one another all the way, being paralleled only at suitable points and mounted on separate insulators. In this case, under favorable conditions one bad conductor could be cut out and the others carry the current with a slightly increased loss. This arrangement has some advantages in maintaining continuity of service in a system exposed to lightning, for it is not likely that all three wires will be broken down simultaneously. In one sense, this arrangement has the flexibility of three circuits, for separate loads can be carried on the three wires provided they are fed from the same bus-bar. They could also feed separate step-down transformers and be paralleled again on the low-tension distributing bus-bar. The tower for such an arrangement would be only slightly larger than that for the single circuit. Of course numerous objections to these various arrangements will appear. Several other arrangements are possible, though perhaps of doubtful practicability.

To show the electrical advantage of the change of ratio of capacity to inductance even where it is not practicable to balance leading and lagging line energy, cases *k* and *l*, Table A, have been calculated. In a 300-mile, 25-cycle transmission, the drop is reduced from 17.1 to 11.4 per cent and the generator power-factor is raised from 0.876 to 0.97.

A number of principles have been here considered, bearing directly on the allowable output and the regulation of long transmission lines. The subjects have been treated in an entirely general way, no effort being made to apply them to a particular installation. The writer wishes to point out that many of the possible arrangements mentioned have been added merely to illuminate the subject and not with the thought that they will be embodied in actual installations. Any particular plant must be a compromise, meeting in the best way the various more or less conflicting demands of full load and light load, voltage regulation, line energy-loss, output and cost of generators, and of line load-factor, operating simplicity, and climatic conditions.

The effectiveness of this proportioning of inductance and capacity in eliminating the effects of capacity and inductance in the transmission line, suggest its application in other work as for example submarine cable work. Here the conditions are different, for it is necessary to deal largely with the transient phenomena, and, further, instead of the line voltage being substantially a constant, it will vary from a maximum to zero, thus tending to give a constantly varying ratio between the leading energy and the lagging energy. Since the electrostatic capacity of the cable greatly exceeds the inductance, an increase of inductance will be required to obtain the necessary balance. This matter will not be treated further here.

SUMMARY

The more important definite conclusions arrived at may be summarized as follows.

1. To obtain the most economical transmission of power over a long-distance line, it is necessary to have balanced the leading and lagging energies of the line itself, and at the same time to have unity power-factor, in which case the transmission is similar to direct-current both as to voltage-drop and energy-loss.

2. The power-factor at the load end may be made unity or otherwise controlled by synchronous machines, generators or motors, located at the receiving end of the line.

3. To obtain satisfactory regulation for high-power long-distance transmission, the leading current taken by the line at light loads should be fed mainly from the receiving end. By this means the voltage-rise from the receiving end; that is, the drop from the power house to the receiving end, can be kept nearly constant for all loads. Adjustment of the line-drop can be accomplished at any load by varying the amounts of the leading energy or charging current supplied to the respective ends of the line.

4. The voltage regulation and line-losses may be controlled for any commercial frequency and for any percentage load condition—as far as its electrical action is concerned—using a conductor of sufficient section, by making the leading and lagging line-energies equal at full load, and by feeding suitable proportions of the charging current at other loads from the respective ends of the line, the greater portion being from the receiving end.

5. The adjustment of the leading and lagging energies taken by the line itself may be accomplished by the choice of voltage and load, or by adjusting the ratio of the capacity and inductance of the line. The latter adjustment can be accomplished effectively by dividing the conductors and spacing them apart a reasonable distance.

6. Calculations of these long high-voltage, high-power lines may be made approximately only by formulas founded on the assumption of localized capacity. The error in the voltage may be several per cent. The approximate formulas are especially unreliable when the leading and lagging energy in the line are equal.

7. Non-synchronous generators are suggested for the power house of a long high-power transmission where it is desired to supply the leading energy for the line from the receiving end. The latter then becomes the controlling and operating point of the system.

8. Constant voltage or suitable compounding should then be maintained at the receiving end and not at the generating end of the system, thus practically eliminating line voltage regulation as a disturbing factor.

9. While it is possible by a cut-and-try method for any given case to arrive at the best condition of capacity, resistance, inductance, and the power-factor at the load end of the line, yet the best result will be obtained most directly by planning the line in accordance with the principles here explained.

While comparatively few high-tension power-transmitting systems now installed are of sufficient magnitude to require as careful a treatment as that outlined here, the development of this art cannot proceed much further without some such method. It is the hope of the writer that here, either directly or, perhaps more likely, by suggestion, he has somewhat forwarded this development.

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(*Subject to final revision for the Transactions.*)

CALCULATION OF THE HIGH-TENSION LINE *

BY PERCY H. THOMAS

Neglecting matters of cost, the electrical performance of the high-tension transmission line becomes the critical factor as the quantity of power and distance of transmission become large. The loss and variation of voltage and, to a lesser extent, perhaps, the loss of energy in the line tend to become the dominating features. A careful study of these characteristics is thus most important in planning such a transmission. It is the purpose of the present paper to discuss the calculation of the high-tension line as relating to the important matters of regulation and energy line loss, and with especial reference to the unusually long and high-power lines. For this purpose certain new formulas suited for practical calculations are derived.

While it has been freely recognized that, strictly speaking, calculations of line quantities should, where appropriate, be made in such a manner as to take cognizance of the fact that the capacity, inductance, and capacity of the line are distributed uniformly, the difficulty of such calculations and the lack of suitable formulas have led to the use of approximations. It may be said that many of these approximations are sufficiently accurate for all ordinary commercial systems. However, in large and very long-distance transmissions the error introduced by the approximations becomes quite noticeable, and while not great enough to seriously threaten the usefulness of the system is too great for a conscientious engineer to neglect.

In the following pages is derived a formula for calculating the true current, voltage, and power-factor at the generator end of a transmission line when the current, voltage, and power-factor at the receiving end are known. This formula is especially adapted to slide-rule work and when once familiar requires relatively little labor.

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* It is intended that this paper shall be considered in connection with a companion paper presented herewith and entitled "Output and Regulation in Long-Distance Lines."

This formula reduces to the usual well-known forms when the resistance, inductance, or the capacity is put equal to 0.

For purposes of comparison an approximate formula is given, used by the writer and based on the much used assumption that the line capacity is concentrated at the ends of the line. This is called the " split-capacity " formula in distinction from the " wave " formula with the distributed capacity first mentioned. The split-capacity formula is exceptionally simple and readily used with a table of cosines and tangents and is believed to be as accurate as any available approximate formula; it would be perfectly accurate were the capacity actually located at the ends of the line as assumed.

To show the relation numerically of the results given by the split-capacity and the wave formulas, Table I is added showing the actual numerical values for a number of selected cases.

The conditions which tend to make a large discrepancy between the two formulas are length, high frequency and low resistance, as well as the particular relation of capacity and inductance energy in the line.

The last column of the table gives the actual phase change due to the time consumed in the passage of the wave through the length of the line as is represented by the quantity $\frac{px}{v}$

DERIVATION OF WAVE FORMULA

Current flow in a uniform conductor containing inductance, capacity, and resistance, distributed, obeys the following laws:

1. Current flowing through resistance produces a drop equal to the product of the current and the resistance at any instant.

2. A varying current produces in an inductance an electromotive force proportional to the rate of change of the current and to the inductance and opposing the current variation.

3. The current to a condenser is proportional to the rate of increase of potential and to the capacity.

From these laws it follows that at any instant

$$\frac{d^2 V}{d x^2} = C R \frac{d V}{d t} + C L \frac{d^2 V}{d t^2} \qquad (1)$$

TABLE I.
COMPARISON OF FORMULAS.

	Distance in miles	Size of conductors	Spacing of conductors	Transmitted power, three phase	Line voltage delivered	Line current load end, "–" means leading	Frequency	Line power-factor, load end	Voltage drop in % of gen. voltage	Line energy loss in % of generator power	Line power-factor gen. end, "–" means leading	Line current, generator end	$\frac{p\,x}{v}\left(\frac{360}{2\,\pi}\right)$	Type of Formula
A	150	#000	7	10000	80000	73.5	25	0.85	10.2	8.6	0.922	66.6	8° 9′	Wave
B	"	"	"	"	"	"	"	"	10.0	8.6	0.920	67.0	—	Sp't Cap.
C	"	"	"	"	"	"	"	"	12.6	7.6	0.985	60.1	18° 13′	Wave
D	"	"	"	"	"	"	60	"	12.9	7.7	0.984	60.1	—	Sp't Cap.
E	700	2 #00	10	40000	150000	142.5	25	0.935	20.5	20.4	–0.950	140.0†	35° 29′	Wave
F	"	"	"	"	"	"	"	"	22.7	20.1	–0.948	136.4	—	Sp't Cap.
G	"	"	"	0	"	–63.8	"	—	1.1	—	—	—	35° 29′	Wave
H	"	"	"	"	"	"	"	—	1.0	—	—	—	—	Sp't Cap.
I	"	3 #0000	12	40000	150000	145.3	25	0.918	12.1	10.4	–0.963	134.8	34° 48′	Wave
K	"	"	"	"	"	"	"	"	13.5	9.5	–0.968	131.5	—	Sp't Cap.
L	"	"	"	60000	"	200	"	1.00	11.5	13.8	–0.994	206.8	34° 48′	Wave
M	"	"	"	"	"	"	"	"	14.1	14.7	–0.996	202.7	—	Sp't Cap.
N	"	"	"	"	"	202	60	0.99	7.2	13.2	–0.974	219.7	83° 6′	Wave
O	"	"	"	"	"	"	"	"	34.0	17.8	–0.941	170.7	—	Sp't Cap.
P	"	(3¼) × #0000	*D** "	75000	"	278	25	0.90	19.6	13.7	–0.988	237	35° 6′	Wave
Q	"	"	*D** "	"	"	"	"	"	25.6	13.8	–0.998	215.7	—	Sp't Cap.
R	75	#0000 lead cable	‡	12000	40000	187.5	"	0.80	15.5	15.7	0.973	154.3	13° 34′	Wave
S	"	"	"	"	"	"	"	"	15.3	15.5	0.973	154.3	—	Sp't Cap.
T	300	$(\frac{3}{2})^2$ ×#0000	10.5	20000	100000	125	60	"	20.2	7.0	0.998	86.1	35° 36′	Wave
U	"	"	"	"	"	"	"	"	21.9	6.9	0.996	84.3	—	Sp't Cap.
V	"	"	"	12000	"	75	"	"	6.2	4.46	–0.873	67.5	35° 36′	Wave
W	"	"	"	"	"	"	"	"	7.4	3.9	–0.89	64.8	—	Sp't Cap.
						142.5	25	93.5	13.9	11.0	1.000	129.0	17° 45′	Wave

† Condition at middle of line.

*D** means divided conductor—each line wire divided into three separate conductors spaçed 18″ apart.

‡ Assumed constants, $R = 0.515$, $p\,L = 0.264$, $p\,C = 0.0000235S$, all per mile

where

V is the potential at any point of the conductor,
R, L, and C are its resistance, inductance, and capacity, respectively, per unit length,
x is the distance of any given point from the end.
t is the time, measured from any starting instant.

This equation may be arrived at as follows: The current flowing to any small element of capacity is $(C\,d\,x)\left(\frac{d\,V}{d\,t}\right)$ where $C\,d\,x$ is the capacity of the short length $d\,x$, see Fig. 1.

This represents the total current subtracted from the current flowing along the conductor to increase the charge in the small condenser $C\,d\,x$, corresponding to the increase in voltage $d\,V$ accomplished in the short time $d\,t$. This small current

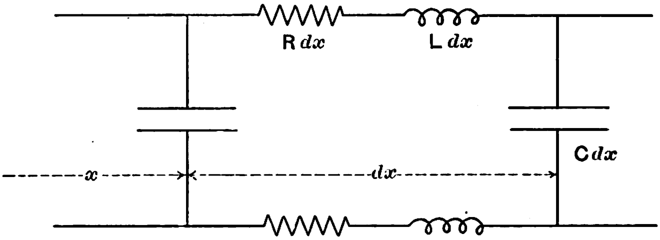

Fig. 1—Elementary section of transmission line

$C\,d\,x\,\frac{d\,V}{d\,t}$ which is subtracted from the current already flowing, causes a resistance drop of

$$(R\,d\,x)\left(C\,d\,x\,\frac{d\,V}{d\,t}\right),$$

since the resistance of the short length $d\,x$ will be $R\;d\,x$. Similarly since the condenser current also flows through the inductance $L\,d\,x$ it will produce a counter voltage

$$(L\,d\,x)\,\frac{d}{d\,t}\left(C\,d\,x\,\frac{d\,V}{d\,t}\right) = C\,L\,d\,x^2\,\frac{d^2\,V}{d\,t^2}$$

Thus

$$R\,C\,d\,x^2\,\frac{d\,V}{d\,t} + L\,C\,d\,x^2\,\frac{d^2\,V}{d\,t^2}$$

gives the voltage caused in the length $d\,x$ by the current flowing to the capacity $C\,d\,x$.

But the voltage difference between the points $x+d\,x$ and x is $(d\,x)\left(\frac{d\,V}{d\,x}\right)$

This voltage difference, however, includes the drop due to the total current flowing in the conductor and not the *variation* of the total drop which is caused by the charging current $C\,d\,x\,\frac{d\,V}{d\,t}$, alone.

Therefore, this *increase* of the total drop due to the current $C\,d\,x\,\frac{d\,V}{d\,t}$ in the length $d\,x$ will be proportional to the rate of increase of

$$d\,x\,\frac{d\,V}{d\,x}, \text{ that is } d\left[d\,x\,\frac{d\,V}{d\,x}\right] = d\,x^2\,\frac{d^2\,V}{d\,x^2}$$

Therefore we have the equation

$$d\,x^2\,\frac{d^2\,V}{d\,x^2} = R\,C\,d\,x^2\,\frac{d\,V}{d\,t} + L\,C\,d\,x^2\,\frac{d^2\,V}{d\,t^2}$$

or dividing by $(d\,x)^2$

$$\frac{d^2\,V}{d\,x^2} = R\,C\,\frac{d\,V}{d\,t} + L\,C\,\frac{d^2\,V}{d\,t^2} \tag{1}$$

This is the usual differential equation for such a circuit. It has been derived, integrated and discussed by many authors, during the last twenty years or more—including Vaschy, Heaviside, Bedelle, Pupin, Leblanc and Steinmetz, the latter three in the Institute Transactions.* All these authors have given solutions in such a general form as to be very awkward for use in connection with actual circuits for numerical computation. Stein-

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*Pupin, vol. xvii, 1900, p. 445.
Leblanc, vol. xix, Transactions, p. 759.
Steinmetz, July 1908 Proceedings, p. 1121.

metz and Leblanc, and presumably the others, have given the necessary equations by which the specific conditions for a given problem can be worked out but this only at great labor.

To return to the derivation of the formula. Having given the above differential equation, it is necessary to find a form of equation without differential quantities, which when differentiated will satisfy this equation (1); that is, to find its primitive. This will be a matter of trial. The above writers have pointed out some suitable forms and of these the most convenient for this case is that of LeBlanc* and Vaschy as follows:

$$V = \varepsilon^{a(l-x)} \left[A \sin\left(p\,t - \frac{p\,x}{v}\right) + B \cos\left(p\,t - \frac{p\,x}{v}\right)\right] + \varepsilon^{-a(l-x)}\left[D \sin\left(p\,t + \frac{p\,x}{v}\right) + F \cos\left(p\,t + \frac{p\,x}{v}\right)\right] \qquad (2)$$

where

l = length of the line.
x the distance from the start
$p = 2\,\pi\,n$ (n = frequency), and where v and α are constants which must be determined to make equation (2) consistent with the differential equation (1). This equation giving the voltage at any point of the circuit will always satisfy the differential equation (1) with such suitable values for the constants α and v. The constants A, B, D, and F, are the constants of integration and can be determined when the terminal voltages or terminal currents are known sufficiently to make the problem actually determinate. In other words equation (2) will be consistent with the differential equation with any values of A, B, C, and D:

This equation (2) is not the most general possible form of primitive equation for the differential equation, since no factors occur having an exponential time function. This form is chosen purposely for the condition here to be studied, that is, the steady condition in which the voltage and current have been flowing long enough to reach a permanent condition, and all the starting disturbances have disappeared.

The value of α and v in equation (2) will next be determined to satisfy the differential equation (1).

The values of

$$\frac{d^2\,V}{d\,x^2},\ R\,C\,\frac{d\,V}{d\,t},\ \text{and}\ L\,C\,\frac{d^2\,V}{d\,t^2}$$

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*Le Blanc, Transactions, vol. xix, 1902, p. 759.

can be determined from equation (2) by differentiating and substituting in (1) namely:

$$\frac{dV}{dt} = \varepsilon^{\alpha(l-x)}\left[pA\cos\left(pt-\frac{px}{v}\right) - pB\sin\left(pt-\frac{px}{v}\right)\right]$$

$$+\varepsilon^{-\alpha(l-x)}\left[pD\cos\left(pt+\frac{px}{v}\right) - pF\sin\left(pt+\frac{px}{v}\right)\right] \quad (3)$$

$$\frac{d^2V}{dt^2} = \varepsilon^{\alpha(l-x)}\left[-p^2A\sin\left(pt-\frac{px}{v}\right) - p^2B\cos\left(pt-\frac{px}{v}\right)\right]$$

$$+\varepsilon^{-\alpha(l-x)}\left[-p^2D\sin\left(pt+\frac{px}{v}\right) - p^2F\cos\left(pt+\frac{px}{v}\right)\right] \quad (4)$$

$$\frac{dV}{dx} = \varepsilon^{\alpha(l-x)}\left[\left(-\alpha A+\frac{p}{v}B\right)\sin\left(pt-\frac{px}{v}\right) + \left(-\alpha B-\frac{p}{v}A\right)\right.$$

$$\left.\times\cos\left(pt-\frac{px}{v}\right)\right] + \varepsilon^{-\alpha(l-x)}\left[\left(\alpha D-\frac{p}{v}F\right)\sin\left(pt+\frac{px}{v}\right)\right.$$

$$\left.+\left(\alpha F+\frac{p}{v}D\right)\cos\left(pt+\frac{px}{v}\right)\right] \quad (5)$$

$$\frac{d^2V}{dx^2} = \varepsilon^{\alpha(l-x)}\left[\left(\frac{\alpha^2v^2-p^2}{v^2}A - \frac{2\alpha p}{v}B\right)\sin\left(pt-\frac{px}{v}\right)\right.$$

$$\left.+\left(\frac{2\alpha p}{v}A+\frac{\alpha^2v^2-p^2}{v^2}B\right)\cos\left(pt-\frac{px}{v}\right)\right]$$

$$+\varepsilon^{-\alpha(l-x)}\left[\left(\frac{\alpha^2v^2-p^2}{v^2}D-\frac{2\alpha p}{v}F\right)\sin\left(pt+\frac{px}{v}\right)\right.$$

$$\left.+\left(\frac{2\alpha p}{v}D+\frac{\alpha^2v^2-p^2}{v^2}F\right)\cos\left(pt+\frac{px}{v}\right)\right] \quad (6)$$

The differential equation (1) must be satisfied by these values so that substituting in equation (1) and rearranging terms, we have

$$\epsilon^{\alpha(l-x)}\left[\left\{\frac{\alpha^2v^2-p^2}{v^2}A-\frac{2\,\alpha\,p}{v}B-R\,C\,(-p\,B)-L\,C\,(-p^2A)\right\}\right.$$

$$\times\sin\left(p\,t-\frac{px}{v}\right)+\left\{\frac{2\alpha\,p}{v}A+\frac{\alpha^2v^2-p^2}{v^2}B-RC(p\,A)-LC(-p^2B)\right\}$$

$$\left.\times\cos\left(p\,t-\frac{px}{v}\right)\right]$$

$$+\,\epsilon^{-\alpha(l-x)}\left[\left\{\frac{\alpha^2v^2-p^2}{v^2}D-\frac{2\,\alpha\,p}{v}F-R\,C\,(-p\,F)-L\,C\,(-p^2\,D)\right\}\right.$$

$$\times\sin\left(p\,t+\frac{px}{v}\right)+\left\{\frac{2\,\alpha\,p}{v}D+\frac{\alpha^2\,v^2-p^2}{v^2}F-RC(pD)-LC(-p^2F)\right\}$$

$$\left.\times\cos\left(p\,t+\frac{px}{v}\right)\right]$$

$$=0$$

This equation must be true for all values of t and for all values of x and for all values of A and B and C and D. This can be true only when each of the four coefficients of the sine and cosine terms is 0.

Therefore

$$\left(\frac{\alpha^2v^2-p^2}{v^2}+p^2\,L\,C\right)A+\left(-\frac{2\,\alpha\,p}{v}+p\,R\,C\right)B=0$$

$$\left(\frac{2\,\alpha\,p}{v}-p\,R\,C\right)A+\left(\frac{\alpha^2\,v^2-p^2}{v^2}+p^2\,L\,C\right)B=0$$

$$\left(\frac{\alpha^2\,v^2-p^2}{v^2}+p^2\,L\,C\right)D+\left(-\frac{2\,\alpha\,p}{v}+p\,R\,C\right)F=0$$

$$\left(\frac{2\,\alpha\,p}{v}-p\,R\,C\right)D+\left(\frac{\alpha^2\,v^2-p^2}{v^2}+p^2\,L\,C\right)F=0$$

But these equations can be zero for all values of A, B, C and D, only if the coefficients of each of these later quantities = 0.

That is

$$\frac{\alpha^2\,v^2-p^2}{v^2}+p^2\,L\,C=0 \tag{7}$$

$$\text{and }\frac{2\,\alpha\,p}{v}-p\,R\,C=0 \tag{8}$$

From equation (8),

$$\alpha = \frac{R\,C\,v}{2} \tag{9}$$

Substituting this value of α in equation (7) and multiplying both sides of the equation by $4\,v^2$

$$R^2\,C^2\,v^4 + 4\,p^2\,L\,C\,v^2 = 4\,p^2$$

$$v^4 + \frac{4\,p^2\,L}{C\,R^2}\,v^2 = \frac{4\,p^2}{C^2\,R^2}$$

$$v^4 + \frac{4\,p^2\,L}{C\,R^2}v^2 + \frac{4\,p^4\,L^2}{C^2\,R^4} = \frac{4\,p^2}{C^2\,R^2} + \frac{4\,p^4\,L^2}{C^2\,R^4}$$

$$v^2 = -\frac{2\,p^2\,L}{C\,R^2} \pm \sqrt{\frac{4\,p^2\,R^2 + 4\,p^4\,L^2}{C^2\,R^4}}$$

$$v = \pm\,\frac{1}{\sqrt{L\,C}}\sqrt{2\,p\,L\left(\frac{-\,p\,L \pm \sqrt{R^2 + p^2\,L^2}}{R^2}\right)}$$

multiplying numerator and denominator under the radical by

$$p\,L \pm \sqrt{R^2 + p^2\,L^2}$$

$$v = \pm\,\frac{1}{\sqrt{L\,C}}\sqrt{\frac{2\,p\,L}{p\,L \pm \sqrt{R^2 + p^2\,L^2}}} \tag{10}$$

Of the four possible values of v represented by the alternative signs and all satisfying the differential equation, only that involving the positive sign will satisfy the physical conditions of the transmission of current.

Equation (2), with equations (9) and (10), thus constitutes a formula, giving a variation of potential along a conductor such that current flow follows the laws of resistance, inductance and capacity, as laid down at the beginning of this discussion and as is shown by its satisfying the differential equation (1). This equation is perfectly determinate except for the four constants A, B, D, and F. If these are chosen in such a way that the equation represents the correct potential of the conductor at any one point it will then represent it at all points.

Before determining these constants for a particular case, however, the equation for the current flow at any point of the same conductor will be determined. Referring to Fig. 1, it is clear that the decrease in the current between the points x and $(x+dx)$ is the capacity $C\,dx$ times the rate of change in voltage at this point, namely

$$(C\,dx)\left(\frac{dV}{dt}\right)$$

Thus, the total current will be

$$-\int\left(\frac{dV}{dt}\right)(C)\,dx+K=-C\int\frac{dV}{dt}\,dx$$

For the constant K will be zero since it may be assumed that there is no current flow existing in the conductor which is independent of time and space.

Equation (3) gives the value of $\frac{dV}{dt}$.

It is evident by inspection that this equation when integrated with respect to x will have the same form as equation (2) but with different coefficients for the sine and cosine terms. It will be simpler to differentiate such a general expression for the current with respect to x and equate the coefficients to those of the expression for

$$-C\frac{dV}{dt}$$

and from these determine the general coefficients assumed in the general equation of current, than to integrate

$$-C\int\frac{dV}{dt}\,dx \quad \text{directly.}$$

Assume, then, that the letters a, b, d and f represent the coefficients of the integrated curve of current, which is taken to have the same form as the equation of potential (2). Here the coefficient a of the current equation corresponds to A of the potential equation, b to B, etc. That is, we may consider that equation (2) is the new integrated current equation assumed, if the quantities A, B, D and F become a, b, d and f with new values. We have then to determine a, b, d and f of the current curve in terms of the quantities in the potential equation. If I is the current, then

$\frac{dI}{dx}$ will be the same form as equation (5),

but with the quantities a, b, d and f substituted for A, B, D and F. But

$$\frac{dI}{dx} = -C\frac{dV}{dt} = -\frac{d}{dx}\int C\frac{dV}{dt}\,dx, \text{ as above.}$$

Therefore the coefficients of the like sine and cosine terms must be equal in this latter equation, see equation (3), and in the modified equation (5).

Therefore

$$p\,C\,A = \frac{p\,a}{v} + \alpha\,b \tag{11}$$

$$p\,C\,B = \frac{p\,b}{v} - \alpha\,a \tag{12}$$

$$p\,C\,D = -\frac{p\,d}{v} - \alpha\,f \tag{13}$$

$$p\,C\,F = -\frac{p\,f}{v} + \alpha\,d \tag{14}$$

From equations (11) and (12),

$$a = p\,v\,C\,\frac{p\,A - \alpha\,v\,B}{p^2 + \alpha^2\,v^2}$$

$$b = p\,V\,C\,\frac{\alpha\,v\,A + p\,B}{p^2 + \alpha^2\,v^2}$$

From equations (13) and (14),

$$d = p\,v\,C\,\frac{-p\,D + \alpha\,v\,F}{p^2 + \alpha^2\,v^2}$$

$$f = p\,v\,C\,\frac{-\alpha\,v\,D - p\,F}{p^2 + \alpha^2\,v^2}$$

substituting these values of a, b, d and f in the equation for current we have

$$I = \frac{p\,v\,C}{p^2+\alpha^2 v^2}\Bigg[\varepsilon^{\alpha(l-x)}\left\{\left(p\,A-\alpha\,v\,B\right)\sin\left(p\,t-\frac{px}{v}\right)+\left(\alpha\,v\,A+p\,B\right)\right.$$
$$\left.\times\cos\left(p\,t-\frac{px}{v}\right)\right\}+\varepsilon^{-\alpha(l-x)}\left\{\left(-p\,D+\alpha\,v\,F\right)\sin\left(p\,t+\frac{px}{v}\right)\right.$$
$$\left.-\left(\alpha\,v\,D+p\,F\right)\cos\left(p\,t+\frac{px}{v}\right)\right\}\Bigg] \qquad (15)$$

the general current equation.

We may now determine the values of A, B, C, and D for the particular case here under discussion; namely, where we have given the current, and voltage, and angle of lag between them, at the receiving end of a conductor. When these constants are then determined, the calculation of the voltage and current and lag angle can be made by the voltage and current equations for any other point of the conductor.

Assume that the received voltage is

$$S\sin\left(p\,t+\theta\right)$$

and the received current is

$$Q\sin p\,t$$

Then if we assume (for convenience) that the receiving end is at the point $x = 0$, we have at the instant when $t = 0$ from equation (2) and equation (15)

$$V_0 = \varepsilon^{\alpha l}B+\varepsilon^{-\alpha l}F = S\sin\theta \qquad (16)$$

$$I_0 = \frac{p\,v\,C}{p^2+\alpha^2 v^2}\left\{\varepsilon^{\alpha l}\left(\alpha\,v\,A+p\,B\right)-\varepsilon^{-\alpha l}\left(\alpha\,v\,D+p\,F\right)\right\} = 0 \qquad (17)$$

And when $p\,t = \frac{\pi}{2}$ we have

$$V_{\frac{\pi}{2}} = \varepsilon^{\alpha l}A+\varepsilon^{-\alpha l}D = S\cos\theta \qquad (18)$$

$$I_{\frac{\pi}{2}} = \frac{p\,v\,C}{p^2+\alpha^2 v^2}\left\{\varepsilon^{\alpha l}\left(p\,A-\alpha\,v\,B\right)-\varepsilon^{-\alpha l}\left(p\,D-\alpha\,v\,F\right)\right\} = -Q \qquad (19)$$

Q is negative, since normal current to the receiving circuit is in the negative direction in the line, as the receiving circuit is at the point $x = 0$.

From equations (17) and (19),

$$\varepsilon^{\alpha l}A - \varepsilon^{-\alpha l}D = -\frac{p\,Q}{p\,v\,C} \tag{20}$$

$$\varepsilon^{\alpha l}B - \varepsilon^{-\alpha l}F = \frac{\alpha\,v\,Q}{p\,v\,C} \tag{21}$$

From equations (18) and (20),

$$A = \frac{1}{2\,\varepsilon^{\alpha l}}\left(-\frac{p\,Q}{p\,v\,C} + S\cos\theta\right) \tag{22}$$

$$D = \frac{1}{2\,\varepsilon^{-\alpha l}}\left(\frac{p\,Q}{p\,v\,C} + S\cos\theta\right) \tag{23}$$

From equations (16) and (21),

$$B = \frac{1}{2\,\varepsilon^{\alpha l}}\left(\frac{\alpha\,v\,Q}{p\,v\,C} + S\sin\theta\right) \tag{24}$$

$$F = \frac{1}{2\,\varepsilon^{-\alpha l}}\left(\frac{-\alpha\,v\,Q}{p\,v\,C} + S\sin\theta\right) \tag{25}$$

and by substituting in equation (2), we have

$$2V = \varepsilon^{-\alpha x}\Big[\Big(\frac{-p\,Q}{p\,v\,C} + S\cos\theta\Big)\sin\Big(p\,t - \frac{px}{v}\Big) + \Big(\frac{\alpha\,v\,Q}{p\,v\,C} + S\sin\theta\Big)$$

$$\times\cos\Big(p\,t - \frac{px}{v}\Big)\Big] + \varepsilon^{\alpha x}\Big[\Big(\frac{p\,Q}{p\,v\,C} + S\cos\theta\Big)\sin\Big(p\,t + \frac{px}{v}\Big)$$

$$-\Big(\frac{\alpha\,v\,Q}{p\,v\,C} - S\sin\theta\Big)\cos\Big(p\,t + \frac{px}{v}\Big)\Big]$$

$$2V = \varepsilon^{-\alpha x}\Big[\frac{Q}{p\,v\,C}\Big\{\Big(-p\sin\Big(p\,t - \frac{px}{v}\Big) + \alpha\,v\cos\Big(p\,t - \frac{px}{v}\Big)\Big\}$$

$$+S\Big\{\cos\theta\sin\Big(p\,t - \frac{px}{v}\Big) + \sin\theta\cos\Big(p\,t - \frac{px}{v}\Big)\Big\}\Big]$$

$$+\varepsilon^{\alpha x}\Big[\frac{Q}{p\,v\,C}\Big\{p\sin\Big(p\,t + \frac{px}{v}\Big) - \alpha\,v\cos\Big(p\,t + \frac{px}{v}\Big)\Big\}$$

$$+S\Big\{\cos\theta\sin\Big(pt+\frac{px}{v}\Big)+\sin\theta\cos\Big(pt+\frac{px}{v}\Big)\Big\}\Big]$$

$$2V=\varepsilon^{-\alpha x}\Big[\frac{Q\sqrt{p^2+\alpha^2v^2}}{pvC}\Big\{\cos\Big(pt-\frac{px}{v}+\tan^{-1}\frac{p}{\alpha v}\Big)\Big\}$$

$$+S\sin\Big(pt-\frac{px}{v}+\theta\Big)\Big]$$

$$+\varepsilon^{\alpha x}\Big[\frac{Q\sqrt{p^2+\alpha^2v^2}}{pvC}\Big\{-\cos\Big(pt+\frac{px}{v}+\tan^{-1}\frac{p}{\alpha v}\Big)\Big\}$$

$$+S\sin\Big(pt+\frac{px}{v}+\theta\Big)\Big]$$

but

$$\frac{\sqrt{p^2+\alpha^2v^2}}{pvC}=\sqrt{\frac{\dfrac{(pL+\sqrt{R^2+p^2L^2})^2+R^2}{(pL+\sqrt{R^2+p^2L^2})^2}}{\dfrac{pC}{pL+\sqrt{R^2+p^2L^2}}}}$$

from equations (9) and (10),

$$=\sqrt{\frac{\sqrt{R^2+p^2L^2}}{pC}}$$

Therefore

$$2V=\varepsilon^{-\alpha x}\Big[Q\sqrt{\frac{\sqrt{R^2+p^2L^2}}{pC}}\Big\{\cos\Big(pt-\frac{px}{v}+\tan^{-1}\frac{p}{\alpha v}\Big)\Big\}$$

$$+S\sin\Big(pt-\frac{px}{v}+\theta\Big)\Big\}\Big]$$

$$+\varepsilon^{\alpha x}\Big[Q\sqrt{\frac{\sqrt{R^2+p^2L^2}}{pC}}\Big\{-\cos\Big(pt+\frac{px}{v}+\tan^{-1}\frac{p}{\alpha v}\Big)\Big\}$$

$$+S\sin\Big(pt+\frac{px}{v}+\theta\Big)\Big\}\Big] \qquad (26)$$

This equation shows the voltage at any point of a line of known resistance, capacity, and inductance, at any instant of time, assuming only that the steady condition has been reached and all starting oscillations have disappeared, and taking the current and voltage at the end of the line as, $Q\sin pt$, and, $S\sin(pt+\theta)$, respectively.

For the purposes of later discussion and for facilitating numerical computation it is convenient to put this equation into a somewhat different form.

Expanding the expressions $\sin\left(pt-\frac{px}{v}+\theta\right)$ and the similar terms, in the form $\sin\left\{\left(pt+\theta\right)\pm\frac{px}{v}\right\}$, etc.,

$$\begin{aligned}V = {} & \frac{\varepsilon^{\alpha x}+\varepsilon^{-\alpha x}}{2}\Big[\Big\{Q\sqrt{\frac{\sqrt{R^2+p^2L^2}}{pC}}\sin\left(pt+\tan^{-1}\frac{p}{\alpha v}\right)\Big\} \\ & \qquad \times \sin\frac{px}{v}+\Big\{S\sin(pt+\theta)\Big\}\cos\frac{px}{v}\Big] \\ & + \frac{\varepsilon^{\alpha x}-\varepsilon^{-\alpha x}}{2}\Big[\Big\{-Q\sqrt{\frac{\sqrt{R^2+p^2L^2}}{pC}}\cos\left(pt+\tan^{-1}\frac{p}{\alpha v}\right)\Big\} \\ & \qquad \times \cos\frac{px}{v}+\Big\{S\cos(pt+\theta)\Big\}\sin\frac{px}{v}\Big] \qquad (27)\end{aligned}$$

It is interesting to notice that the quantities $\frac{\varepsilon^{\alpha x}+\varepsilon^{-\alpha x}}{2}$ and $\frac{\varepsilon^{\alpha x}-\varepsilon^{-\alpha x}}{2}$ are respectively the hyperbolic cosine and hyperbolic sine of αx respectively; that is, are $\cosh \alpha x$ and $\sinh \alpha x$, respectively.

Returning now to the current equation and substituting in equation (15), the values of the constants A, B, D and F as found in equation (22), (23), (24) and (25).

$$\begin{aligned}2I = {} & \frac{pvC}{p^2+\alpha^2v^2}\Big[\varepsilon^{-\alpha x}\Big\{\Big[p\Big(-\frac{pQ}{pvC}+S\cos\theta\Big) \\ & -\alpha v\Big(\frac{\alpha vQ}{pvC}+S\sin\theta\Big)\Big]\sin\Big(pt-\frac{px}{v}\Big) \\ & +\Big[\alpha v\Big(-\frac{pQ}{pvC}+S\cos\theta\Big)+p\Big(\frac{\alpha vQ}{pvC}+S\sin\theta\Big)\Big] \\ & \qquad \times \cos\Big(pt-\frac{px}{v}\Big)\Big\}\end{aligned}$$

$$+\varepsilon^{\alpha x}\left\{\left[-p\left(\frac{pQ}{pvC}+S\cos\theta\right)+\alpha v\left(\frac{-\alpha vQ}{pvC}\right.\right.\right.$$

$$\left.\left.+S\sin\theta\right)\right]\sin\left(pt+\frac{px}{v}\right)-\left[\alpha v\left(\frac{pQ}{pvC}+S\cos\theta\right)\right.$$

$$\left.\left.+p\left(\frac{-\alpha vQ}{pvC}+S\sin\theta\right)\right]\cos\left(pt+\frac{px}{v}\right)\right]\Bigg\}$$

rearranging and simplifying terms:

$$2I=\varepsilon^{-\alpha x}\left\{-Q\sin\left(pt-\frac{px}{v}\right)+S\frac{pvC}{p^2+\alpha^2v^2}\Big[(p\cos\theta\right.$$

$$-\alpha v\sin\theta)\sin\left(pt-\frac{px}{v}\right)+(\alpha v\cos\theta+p\sin\theta)\Big]$$

$$\left.\times\cos\left(pt-\frac{px}{v}\right)\right\}$$

$$+\varepsilon^{\alpha x}\left\{-Q\sin\left(pt+\frac{px}{v}\right)+S\frac{pvC}{p^2+\alpha^2v^2}\Big[(-p\cos\theta\right.$$

$$\left.+\alpha v\sin\theta)\sin\left(pt+\frac{px}{v}\right)-(\alpha v\cos\theta+p\sin\theta)\Big]\cos\left(pt+\frac{px}{v}\right)\right\}$$

$$2I=\varepsilon^{-\alpha x}\left\{-Q\sin\left(pt-\frac{px}{v}\right)+S\frac{pvC}{\sqrt{p^2+\alpha^2v^2}}\right.$$

$$\times\left[-\sin\left(\theta-\tan^{-1}\frac{p}{\alpha v}\right)\sin\left(pt-\frac{px}{v}\right)\right.$$

$$\left.\left.+\cos\left(\theta-\tan^{-1}\frac{p}{\alpha v}\right)\cos\left(pt-\frac{px}{v}\right)\right]\right\}$$

$$+\varepsilon^{\alpha x}\left\{-Q\sin\left(pt+\frac{px}{v}\right)+S\frac{pvC}{\sqrt{p^2+\alpha^2v^2}}\right.$$

$$\times \left[\sin \left(\theta - \tan^{-1} \frac{p}{\alpha\, v}\right) \sin \left(p\, t + \frac{p\, x}{v}\right) - \cos \left(\theta - \tan^{-1} \frac{p}{\alpha\, v}\right) \right.$$

$$\left. \cos \left(p\, t + \frac{p\, x}{v}\right) \right]\Bigg\}$$

$$-2\, I = \varepsilon^{-\alpha x} \Bigg\{ Q \ \sin \ \left(p\, t - \frac{p\, x}{v}\right) - S \sqrt{\frac{p\, C}{\sqrt{R^2 + p^2\, L^2}}}$$

$$\times \left[\cos \left(p\, t + \theta - \frac{p\, x}{v} - \tan^{-1} \frac{p}{\alpha\, v}\right) \right]$$

$$+ \varepsilon^{\alpha x} \Bigg\{ Q \ \sin \ \left(p\, t + \frac{p\, x}{v}\right) + S \sqrt{\frac{p\, C}{\sqrt{R^2 + p^2\, L^2}}}$$

$$\left[+ \cos \ \left(p\, t + \theta + \frac{p\, x}{v} - \tan^{-1} \frac{p}{\alpha\, v}\right) \right] \qquad (28)$$

since as already shown

$$\frac{p\, v\, C}{\sqrt{p^2 + \alpha^2\, v^2}} = \sqrt{\frac{p\, C}{\sqrt{R^2 + p^2\, L^2}}}$$

This equation shows the current at any point of the line for which equation (26) shows the voltage.

This equation can be put into a form similar to equation (27) by expanding the sine and cosine terms as before.

Thus,

$$-I = \frac{\varepsilon^{\alpha x} + \varepsilon^{-\alpha x}}{2} \left[Q \sin p\, t \cos \frac{p\, x}{v} - S \sqrt{\frac{p\, C}{\sqrt{R^2 + p^2\, L^2}}} \right.$$

$$\left. \times \left(\sin \left(p\, t + \theta - \tan^{-1} \frac{p}{\alpha\, v}\right) \sin \frac{p\, x}{v} \right) \right]$$

$$+ \frac{\varepsilon^{\alpha x} - \varepsilon^{-\alpha x}}{2} \left[Q \cos p\, t \sin \frac{p\, x}{v} + S \sqrt{\frac{p\, C}{\sqrt{R^2 + p^2\, L^2}}} \right.$$

$$\left. \times \left(\cos \left(p\, t + \theta - \tan^{-1} \frac{p}{\alpha\, v}\right) \cos \frac{p\, x}{v} \right) \right] \qquad (29)$$

The current is negative in equations (28) and (29), since when the potential rises in the positive direction from the origin, the current is in the opposite direction toward the origin.

The equations (27) and (29) give a second form of the exact equations (26) and (28) for the voltage and current at any point along a line when the current and voltage delivered by the line at the origin are

$Q \sin p\,t$ and $S \sin (p\,t+\theta)$ respectively.

SPECIAL CASES

These values should hold for the special cases where C, or L or $R = O$.

First case.

If $C = 0$,

$$\alpha = 0,\ \frac{p\,x}{v} = x\sqrt{\frac{pC}{2}(p\,L+\sqrt{R^2+p^2\,L^2})} = 0,$$

$$\frac{p}{\alpha\,v} = \frac{p\,L+\sqrt{R^2+p^2\,L^2}}{R}$$

and equation (27) becomes.

$$V = Q\sqrt{\sqrt{R^2+p^2\,L^2}}\left[\sin\left(p\,t+\tan^{-1}\frac{p}{\alpha\,v}\right)\left\{\frac{\sin\frac{px}{v}}{\sqrt{pC}}\right\}\right.$$

$$\left.-\cos\left(p\,t+\tan^{-1}\frac{p}{\alpha\,v}\right)\left(\frac{\frac{\varepsilon^{\alpha x}-\varepsilon^{-\alpha x}}{2}}{\sqrt{p\,C}}\right)\right]+S\sin(p\,t+\theta)$$

But the expressions $\frac{\sin\frac{p\,x}{v}}{\sqrt{p\,C}}$ and $\frac{\frac{\varepsilon^{\alpha x}-\varepsilon^{-\alpha x}}{2}}{\sqrt{p\,C}}$ both become $\frac{0}{0}$ when $C = 0$ and hence are indeterminate. As $\sin\frac{p\,x}{v}$ becomes 0, it equals $\frac{p\,x}{v}$. Thus substituting for, $\sin\frac{p\,x}{v}$, its value in the limit, $\frac{p\,x}{v}$,

$$\frac{\sin\frac{p\,x}{v}}{\sqrt{p\,C}} = \frac{\frac{p\,x}{v}}{\sqrt{p\,C}} = x\sqrt{\frac{p\,L+\sqrt{R^2+p^2\,L^2}}{2}}$$ which is determinate.

The expression

$$\frac{\dfrac{\varepsilon^{\alpha x}-\varepsilon^{-\alpha x}}{2}}{\sqrt{p\,C}}$$

may be evaluated by differentiating numerator and denominator with regard to c and again putting $C=0$.

Then

$$\frac{\dfrac{\varepsilon^{\alpha x}-\varepsilon^{-\alpha x}}{2}}{\sqrt{p\,C}}=\frac{\dfrac{R\,x}{2}\sqrt{\dfrac{2\,p}{p\,L+\sqrt{R^2+p^2\,L^2}}}\left(\dfrac{1}{2}\sqrt{\dfrac{1}{C}}\right)\left(\dfrac{\varepsilon^{\alpha x}+\varepsilon^{-\alpha x}}{2}\right)}{\frac{1}{2}\sqrt{p}\sqrt{\dfrac{1}{C}}}$$

$$=Rx\sqrt{\frac{1}{2\,(p\,L+\sqrt{R^2+p^2\,L^2}}}$$

Therefore

$$V=x\,Q\sqrt{\sqrt{R^2+p^2\,L^2}}\left[\sqrt{\frac{p\,L+\sqrt{R^2+p^2\,L^2}}{2}}\,\sin\left(p\,t+\tan^{-1}\frac{p}{\alpha v}\right)\right.$$

$$\left.-R\sqrt{\frac{1}{2\,(p\,L+\sqrt{R^2+p^2L^2})}}\,\cos\left(p\,t+\tan^{-1}\frac{p}{\alpha\,v}\right)\right]$$

$$+S\sin\,(p\,t+\theta)$$

combining sine and cosine terms

$$V=x\,Q\sqrt{\sqrt{R^2+p^2\,L^2}}$$

$$\times\sqrt{\left(\sqrt{\frac{p\,L+\sqrt{R^2+p^2\,L^2}}{2}}\right)^2+\left(R\sqrt{\frac{1}{2\,(p\,L+\sqrt{R^2+p^2\,L^2}}}\right)^2}$$

$$\sin\left(p\,t+\tan^{-1}\frac{p}{\alpha\,v}-\tan^{-1}\frac{R}{p\,L+\sqrt{R^2+p^2\,L^2}}\right)+S\sin\,(p\,t+\theta)$$

The two radicals forming the coefficient of the *sine* combined

$$=\sqrt{\sqrt{R^2+p^2\,L^2}}\sqrt{\frac{p\,L+\sqrt{R^2+p^2\,L^2}}{2}+\frac{R^2}{2(p\,L+\sqrt{R^2+p^2\,L^2})}}$$

$$=\sqrt{\sqrt{R^2+p^2\,L^2}}\sqrt{\frac{2\,(p^2\,L^2+R^2+p\,L\sqrt{R^2+p^2\,L^2})}{2\,(p\,L+\sqrt{R^2+p^2\,L^2})}}$$

$$=\sqrt{\sqrt{R^2+p^2\,L^2}}\sqrt{\sqrt{R^2+p^2\,L^2}}=\sqrt{R^2+p^2\,L^2}$$

The tan of the difference of the two angles $\tan^{-\prime} p/\alpha v$ and

$$\tan^{-\prime}\frac{R}{p\,L+\sqrt{R^2+p^2\,L^2}}$$

$$= \tan^{-\prime}\frac{\dfrac{p\,L+\sqrt{R^2+p^2\,L^2}}{R}-\dfrac{R}{p\,L+\sqrt{R^2+p^2\,L^2}}}{1+\dfrac{p\,L+\sqrt{R^2+p^2\,L^2}}{R}\cdot\dfrac{R}{p\,L+\sqrt{R^2+p^2\,L^2}}}$$

$$= \tan^{-\prime}\frac{\dfrac{2\,p^2\,L^2+2\,p\,L\sqrt{R^2+p^2\,L^2}}{R\,(p\,L+\sqrt{R^2+p^2 L^2})}}{2} = \tan^{-\prime}\frac{p\,L}{R}$$

Therefore,

$$V = x\,Q\sqrt{R^2+p^2\,L^2}\sin\left(p\,t+\tan^{-\prime}\frac{p\,L}{R}\right)+S\sin\,(p\,t+\theta) \qquad (30)$$

where $x\sqrt{R^2+p^2\,L^2}$ is the total impedance of the line.

This is seen to be the usual voltage formula for an inductive current.

With $C = 0$, from equation (29),

$$I = -Q\sin p\,t, \qquad (31)$$

as must be the case since, in the absence of capacity, no loss or gain of current can occur along the conductor.

Second case.

If $L = 0$, $\dfrac{p\,x}{v} = x\sqrt{\dfrac{p\,R\,C}{2}}$, $\alpha = \sqrt{\dfrac{p\,R\,C}{2}}$, $\dfrac{p}{\alpha\,v} = 1$

Equation (27) becomes

$$V=\frac{\varepsilon^{x\sqrt{(pRC)\div 2}}+\varepsilon^{-x\sqrt{(pRC)\div 2}}}{2}\left[Q\sqrt{\frac{R}{p\,C}}\sin\left(p\,t+\frac{\pi}{4}\right)\sin x\sqrt{\frac{p\,R\,C}{2}}\right.$$
$$\left.+S\sin\,(p\,t+\theta)\cos x\sqrt{\frac{p\,R\,C}{2}}\right]$$
$$+\frac{\varepsilon^{x\sqrt{(pRC)\div 2}}-\varepsilon^{-x\sqrt{(pRC)\div 2}}}{2}\left[-Q\sqrt{\frac{R}{p\,C}}\sin\left(p\,t+\frac{\pi}{4}\right)\right.$$
$$\left.\times\cos x\sqrt{\frac{p\,R\,C}{2}}+S\cos\,(p\,t+\theta)\sin x\sqrt{\frac{p\,R\,C}{2}}\right] \qquad (32)$$

Equation (29) becomes

$$-I = \frac{\varepsilon^{x\sqrt{(pRC)\div 2}}+\varepsilon^{-x\sqrt{(pRC)\div 2}}}{2}\left[Q \sin p\,t \cos x \sqrt{\frac{p\,R\,C}{2}}\right.$$

$$\left. - S\sqrt{\frac{p\,C}{R}}\,\sin\left(p\,t+\theta-\frac{\pi}{4}\right)\sin x\sqrt{\frac{p\,R\,C}{2}}\right]$$

$$+\frac{\varepsilon^{x\sqrt{(pRC)\div 2}}-\varepsilon^{-x\sqrt{(pRC)\div 2}}}{2}\left[Q \cos p\,t \sin x \sqrt{\frac{p\,R\,C}{2}}\right.$$

$$\left. + S\sqrt{\frac{p\,C}{R}}\,\cos\left(p\,t+\theta-\frac{\pi}{4}\right)\cos x\sqrt{\frac{p\,R\,C}{2}}\right] \qquad (33)$$

Third case.

If $R = 0$,

$$\frac{p\,x}{v} = x\sqrt{p^2\,L\,C},\ \frac{p}{\alpha\,v} = \infty,\ \alpha = 0$$

Equation (27) becomes

$$V = Q\sqrt{\frac{L}{C}}\cos p\,t \sin x\sqrt{p^2 L C}+S \sin\,(p\,t+\theta)\cos x\sqrt{p^2\,L\,C} \qquad (34)$$

Equation (29) becomes

$$-I = Q \sin p\,t \cos x\sqrt{p^2\,L\,C}+S\sqrt{\frac{C}{L}}\cos\,(p\,t+\theta)\sin x\sqrt{p^2 L C} \qquad (35)$$

Other cases. If $R = 0$ as well as C from equation (30) [or if $C = 0$ as well as R in equation (34)]

$$V = p\,L\,x\,Q \cos p\,t+S \sin\,(p\,t+\theta)$$

where $x\,p\,l$ = total inductance of the line.

If $L = 0$ as well as C from equation (30)

$$V = x\,R\,Q \sin p\,t+S \sin\,(p\,t+\theta)$$

where $x\,R$ is the total resistance of the line.

If $L = 0$ as well as R in equation (34),

$$V = S \sin (p\,t + \theta)$$

and from equation (35)

$$-I = Q \sin p\,t + S \sqrt{C} \cos (p\,t + \theta) \left(\frac{\sin x \sqrt{p^2 L C}}{\sqrt{L}} \right)$$

The expression $\dfrac{\sin x \sqrt{p^2 L C}}{\sqrt{L}} = \dfrac{0}{0}$. As before in the limit

$\sin x \sqrt{p^2 L C} = x \sqrt{p^2 L C}$

therefore

$$-I = +Q \sin p\,t + p\,C\,x\,S \cos (p\,t + \theta)$$

This is the well-known formula for a shunt condenser, where $C\,x$ = total capacity of the line.

Thus in the various special cases where the quantities, voltage and current, cease to be wave functions, the general equations reduce to the well-known forms, but in each case the change from the wave function to the simple function is through the evaluation of an indeterminate form.

As long as the line contains capacity and either resistance or inductance these functions are in wave form as they include trigonometrical functions of angles including the distance x from the origin. In other cases the formulas represent the algebraic form of function.

PHYSICAL MEANING OF EQUATIONS

Equations (26) and (28) give perhaps the best idea of the physical nature of the phenomenon of voltage and current variation. As a matter of fact there exists only a single resultant succession of waves passing in the line. It is helpful sometimes, however, to consider that the resultant wave is made up of a number of component waves.

Suppose, for example, that a perfectly uncharged line be connected to a source of sine electromotive force. A wave will pass into the line and will lose a little of its energy or amplitude as it passes along, and at the end will be reflected and pass backward along the line in the same manner, getting gradually less all the way. This wave reaching the generator will be absorbed while the generator continues to send out similar waves.

Considering now the receiving end where the potential waves are reflected and the neighborhood of this point, there are at all times two component potential waves at each point in the line, one going toward the reflecting point and the other coming from it. These waves remain the same as they travel, except for decrease in amplitude due to the resistance losses, and for their phase which is, of course, further advanced in the time angle and less advanced by the space angle in the leading wave. The reflected potential wave is represented by the term

$$S \sin \left(p\,t - \frac{p\,x}{v} + \theta\right)$$

and the direct wave by the expression

$$S \sin \left(p\,t + \frac{p\,x}{v} + \theta\right)$$

the angle $\frac{p\,x}{v}$ being the part of a cycle ($2\,\pi$) occupied by the wave in passing over the distance x to or from the point of reflection. But the current produces a drop in the line, proportional to the current and square root of the impedance, and inversely proportional to the square root of the capacity susceptance, as is shown by the equation (26). The current wave passes along together with the potential wave toward the reflecting point, being represented by the expression

$$Q \sin \left(p\,t + \frac{p\,x}{v}\right)$$

Similarly with the reflected current wave

$$Q \sin \left(p\,t - \frac{p\,x}{v}\right)$$

which passes back through the line from the reflecting point. But the potential due to the current wave is not in phase with the current but occurs earlier than the current by the angle

$$\tan^{-\prime} \frac{p}{\alpha\,v} = \tan^{-\prime} \frac{p\,L + \sqrt{R^2 + p^2\,L^2}}{R}$$

Again the direction of the drop in line, produced by the current wave after reflection, is opposite with regard to the voltage from that due to the direct current-wave. This appears in the equation by the positive sign of the quantity

$$+Q\sqrt{\frac{\sqrt{R^2+p^2L^2}}{pC}}\cos\left(pt-\frac{px}{v}+\tan^{-\prime}\frac{p}{\alpha v}\right),$$ representing

the reflected wave.

Thus the total resultant voltage is the combination of these four quantities, the direct and reflected potential waves, which decrease as they travel, as indicated by the two factors: first,

$$e^{\alpha x}.$$

indicating that the direct wave is greater than the value at the reflecting point, since it will decrease somewhat by travelling along the line tothe reflecting point; and, second, by the factor

$$e^{-\alpha x},$$

indicating that the reflected wave is less than the value at the reflecting point, since it has passed along the line some distance from this point, and the direct and reflected current wave drops.

Since Q and S, however, should be the total delivered current and voltage but momentarily taken for the maximum value of each wave, the sum of the four waves will be twice the actual voltage, as is shown by the equation (26).

Similarly with the current formula (28) where the resultant current is made up of four elements, the direct and reflected current waves which diminish as they travel at the rate $e^{\alpha x}$, and a direct and reflected curve due to the effect of the voltage wave and consisting of charging current. The direct current wave, due to the direct voltage wave, is represented by the expression

$$S\sqrt{\frac{pC}{\sqrt{R^2+p^2L^2}}}\sin\left(pt+\frac{px}{v}+\theta-\tan^{-\prime}\frac{p}{\alpha v}\right)$$

The phase angle here shown is due partly to the ordinary time variation $(p\,t)$, partly to the distance it has to pass to reach the reflecting point $\frac{px}{v}$, partly to the lead of the delivered voltage over the current (θ) and partly due to the lag between the charging current wave and the voltage wave causing it, $\tan^{-1} \frac{p}{\alpha v}$

Similarly with the phase of the corresponding reflected wave, in which, however, the wave has passed the reflecting point and is thus earlier than the waves at that point by the angle $\frac{p x}{v}$.*

Again it will be noticed that while the component current waves are sine quantities, the charging current waves produced by the voltage waves appear as cosine quantities. This is because the charging current is primarily proportional to the rate of change of voltage and not directly to the voltage. The cosine, of course, gives the rate of change of the sine.

NUMERICAL CALCULATIONS BY WAVE FORMULA

Numerical calculations. For purposes of numerical calculation these equations can be considerably simplified. Starting with equation (27) the voltage is seen to be the summation of four terms, sines and cosines, having varying phase relations. The simplest way to determine the maximum value of the resultant wave, numerically in a given case, is to substitute in the equation separately two values of $p\,t$, 90 degrees apart, and the square root of the sum of the squares of the results of these substitutions will be the resultant maximum. In this case $p\,t$ will be put $= 0$ and then $= \pi/2$.

Then equation (27) gives for $p\,t = 0$

$$V_0 = \left[S \sin\theta \cos\frac{p x}{v} + Q \sqrt{\frac{\sqrt{R^2 + p^2 L^2}}{p C}} \sin \tan^{-1}\frac{p}{\alpha v} \times \sin\frac{p x}{v} \right] \frac{\varepsilon^{\alpha x} + \varepsilon^{-\alpha x}}{2} + \left[S \cos\theta \sin\frac{p x}{v} - Q \sqrt{\frac{\sqrt{R^2 + p^2 L^2}}{p C}} \times \cos \tan^{-1}\frac{p}{\alpha v} \cos\frac{p x}{v} \right] \frac{\varepsilon^{\alpha x} - \varepsilon^{-\alpha x}}{2} \qquad (36)$$

---

* In this connection, attention is called to the writer's paper before the A. I. E. E. of February, 1902, Transactions, vol. xiv, p. 213, where a somewhat similar, non-mathematical, description of electric waves is given. The equations here derived conform exactly to the principles there laid down.

For $p\,t = \frac{\pi}{2}$

$$V_{\frac{\pi}{2}} = \Bigg[S \cos\theta \cos\frac{p\,x}{v} + Q \sqrt{\frac{\sqrt{R^2+p^2\,L^2}}{p\,C}} \cos\tan^{-1}\frac{p}{\alpha\,v}$$

$$\times \sin\frac{p\,x}{v}\Bigg] \frac{\varepsilon^{\alpha x}+\varepsilon^{-\alpha x}}{2} + \Bigg[-S\sin\theta\sin\frac{p\,x}{v}$$

$$+\ Q\sqrt{\frac{\sqrt{R^2+p^2L^2}}{p\,C}} \sin\tan^{-1}\frac{p}{\alpha\,v} \cos\frac{p\,x}{v}\Bigg] \frac{\varepsilon^{\alpha x}-\varepsilon^{-\alpha x}}{2} \qquad (37)$$

Similarly, with equation (29) putting $p\,t = 0$

$$-I_0 = \Bigg[0 + S\sqrt{\frac{p\,C}{\sqrt{R^2+p^2\,L^2}}}\ \Bigg(-\sin\Bigg(\theta - \tan^{-1}\frac{p}{\alpha\,v}\Bigg)$$

$$\times\sin\frac{p\,x}{v}\Bigg)\Bigg] \frac{\varepsilon^{\alpha x}+\varepsilon^{-\alpha x}}{2} + \Bigg[Q\sin\frac{p\,x}{v} + S\sqrt{\frac{p\,C}{\sqrt{R^2+p^2\,L^2}}}$$

$$\times\Bigg(\cos\ \Bigg(\theta - \tan^{-1}\frac{p}{\alpha\,v}\Bigg)\cos\frac{p\,x}{v}\Bigg)\Bigg] \frac{\varepsilon^{\alpha x}-\varepsilon^{-\alpha x}}{2} \qquad (38)$$

putting $p\,t = \frac{\pi}{2}$

$$-I_{\frac{\pi}{2}} = \Bigg[\ Q\sin\frac{p\,x}{v} + S\sqrt{\frac{p\,C}{\sqrt{R^2+p^2L^2}}}\Bigg(-\cos\Bigg(\theta - \tan^{-1}\frac{p}{\alpha\,v}\Bigg)$$

$$\times\sin\frac{p\,x}{v}\Bigg)\Bigg] \frac{\varepsilon^{\alpha x}+\varepsilon^{-\alpha x}}{2} + \Bigg[0 + S\sqrt{\frac{p\,C}{\sqrt{R^2+p^2L^2}}}$$

$$\times\ \Bigg(-\sin\Bigg(\theta - \tan\frac{p}{\alpha\,v}\Bigg)\cos\ \frac{p\,x}{v}\Bigg)\Bigg] \frac{\varepsilon^{\alpha x}-\varepsilon^{-\alpha x}}{2} \qquad (39)$$

Rearranging terms and putting $\frac{\varepsilon^{\alpha x}+\varepsilon^{-\alpha x}}{2} = k_1$ and

$$\frac{\varepsilon^{\alpha x}-\varepsilon^{-\alpha x}}{2} = k_2$$

FORMULAS FOR NUMERICAL CALCULATIONS.

$$V_0=S\left(\left(k_1\cos\frac{px}{v}\right)\sin\theta+\left(k_2\sin\frac{px}{v}\right)\cos\theta\right)+Q\sqrt{\frac{\sqrt{R^2+p^2L^2}}{pC}}\left(\left(k_1\sin\frac{px}{v}\right)\sin\tan^{-1}\frac{p}{\alpha v}-\left(k_2\cos\frac{px}{v}\right)\cos\tan^{-1}\frac{p}{\alpha v}\right) \quad (40)$$

$$V_{\frac{\pi}{2}}=S\left(\left(\text{“}\quad\text{“}\right)\cos\theta-\left(\text{“}\quad\text{“}\right)\sin\theta\right)+Q\sqrt{\frac{\sqrt{R^2+p^2L^2}}{pC}}\left(\left(\text{“}\quad\text{“}\right)\cos\tan^{-1}\frac{p}{\alpha v}+\left(\text{“}\quad\text{“}\right)\sin\tan^{-1}\frac{p}{\alpha v}\right) \quad (41)$$

$$I_0= \qquad +\left(\text{“}\quad\text{“}\right)Q+S\sqrt{\frac{pC}{\sqrt{R^2+p^2L^2}}}\left(\left(\text{“}\quad\text{“}\right)\sin\left(\tan^{-1}\frac{p}{\alpha v}-\theta\right)+\left(\text{“}\quad\text{“}\right)\cos\left(\tan^{-1}\frac{p}{\alpha v}-\theta\right)\right) \quad (42)$$

$$I_{\frac{\pi}{2}}=\left(\text{“}\quad\text{“}\right)Q \qquad -S\sqrt{\frac{pC}{\sqrt{R^2+p^2L^2}}}\left(\left(\text{“}\quad\text{“}\right)\cos\left(\tan^{-1}\frac{p}{\alpha v}-\theta\right)-\left(\text{“}\quad\text{“}\right)\sin\left(\tan^{-1}\frac{p}{\alpha v}-\theta\right)\right) \quad (43)$$

Note, as determined below :

$$V=\sqrt{V_0^2+V_{\frac{\pi}{2}}^2}=V_0\div\sin\tan^{-1}\frac{V_0}{V_{\frac{\pi}{2}}}=V_{\frac{\pi}{2}}\div\cos\tan^{-1}\frac{V_0}{V_{\frac{\pi}{2}}};\ I=\sqrt{I_0^2+I_{\frac{\pi}{2}}^2}=I_0\div\sin\tan^{-1}\frac{I_0}{I_{\frac{\pi}{2}}}=I_{\frac{\pi}{2}}\div\cos\tan^{-1}\frac{I_0}{I_{\frac{\pi}{2}}}$$

Generator power factor $=\cos\left(\tan^{-1}\frac{V_0}{V_{\frac{\pi}{2}}}-\tan^{-1}\frac{I_0}{I_{\frac{\pi}{2}}}\right)$, line energy loss $= V\,I$ (gen. P. F.) $- S\,Q\cos\theta$

$k_1=1+\frac{\alpha^2x^2}{2}$, $k_2=\alpha x\left(1+\frac{\alpha^2x^2}{6}\right)$, load voltage $= S$, load current $= Q$, load power factor $=\cos\theta$

Then

$$V = \sqrt{V_0^2 + V_{\frac{\pi}{2}}^2}, \quad I = \sqrt{I_0^2 + I_{\frac{\pi}{2}}^2}$$

These equations serve to give the calculation of generator current and voltage in actual cases. It is more convenient instead of using the expressions $\sqrt{V_0^2 + V_{\frac{\pi}{2}}^2}$ and $\sqrt{I_0^3 + I_{\frac{\pi}{2}}^2}$ to consider the trigonometrical relations of the quantities V_0, $V_{\frac{\pi}{2}}$, I_0, and $I_{\frac{\pi}{2}}$, graphically in their triangles, in this case

$$V = V_0 \div \sin \tan^{-1} \frac{V_0}{V_{\frac{\pi}{2}}} \text{ and } I = I_0 \div \sin \tan^{-1} \frac{I_0}{I_{\frac{\pi}{2}}} \quad (44) \quad (45)$$

The phase angle by which the current lags behind the voltage at the generator is the difference in the phase angles of the two resultant quantities just determined, namely, the angles, $\tan^{-1} \frac{V_0}{V_{\frac{\pi}{2}}}$ and $\tan^{-1} \frac{I_0}{I_{\frac{\pi}{2}}}$. The power-factor of the generator power is the cosine of this angle

$$\cos\left(\tan^{-1} \frac{V_0}{V_{\frac{\pi}{2}}} - \tan^{-1} \frac{I_0}{I_{\frac{\pi}{2}}}\right)$$

The generator conditions are thus completely determined. In making calculations it should be noted that

$$\frac{\varepsilon^{\alpha x} + \varepsilon^{-\alpha x}}{2} = k_1 = 1 + \frac{\alpha^2 x^2}{1 \alpha 2} + \frac{\alpha^4 x^4}{1.2.3.4} + \dots .$$

and that

$$\frac{\varepsilon^{\alpha x} - \varepsilon^{-\alpha x}}{2} = k_2 = \alpha x + \frac{\alpha^3 x^3}{1.2.3} + \frac{\alpha^5 x^5}{1.2.3.4.5} + \dots .$$

Two terms of these series are always accurate enough for numerical calculations.

$\sqrt{R^2 + p^2 L^2}$ is of course the impedance per unit length of line. Any convenient unit of length may be taken provided it is used throughout.

In actual calculations the following procedure is recommended:

Having given:

Length line, 700 miles.
Size conductors, 3 No. 0000.
Spacing wires, 12 foot triangle.
Power delivered, 40,000 three phase, 20,000 in single phase for equivalent drop.
Voltage delivered 150,000.
Power factor of delivered power, .918.
Current delivered, 145, single phase.

Take from tables:

Resistance of line per loop unit length $= R = .17$ ohms.
Inductive ohms $= p\,L$ (L in henries) $= 2\,\pi\,n\,L = .619$ ohms.
Impedance ohms $= \sqrt{R^2+p^2\,L^2} = \ldots\ldots\ldots\ldots\, .643$ ohms
Capacity susceptance $= p\,C = 2\,\pi\,n\,C$
= charging current per volt (capacity must be in farads,
= capacity in microfarads $\div 10^6$) $= \ldots\ldots\ldots\ldots .000001193$

By calculation,

Cos $\theta = .918$, $\theta = 23°, 20'$, sin $\theta = .400$.

$$\frac{p\,x}{v} = x\sqrt{\frac{p\,C\,(p\,L+\sqrt{R^2+p^2L^2})}{2}}$$

$$= x\sqrt{\frac{\text{cap. suscept. (induct. + imped.)}}{2}}$$

$$= 700\sqrt{\frac{.000001193}{2}\,(.619+.643)} = .607$$

To get .607 into degrees multiply by $\frac{360}{2\,\pi}$

$$.607 \times \frac{360}{2\,\pi} = 34°, 48'$$

$$\sin\frac{p\,x}{v} = .571, \quad \cos\frac{p\,x}{v} = .821$$

$$\frac{p}{\alpha\,v} = \frac{p\,L+\sqrt{R^2+p^2\,L^2}}{R} = \frac{.619+.643}{.17} = 7.43$$

$$\tan^{-1} 7.43 = 82^\circ\ 20', \ \sin\tan^{-1}\frac{p}{\alpha v} = .991, \cos\tan^{-1}\frac{p}{\alpha v} = .133$$

$$\left(\tan^{-1}\frac{p}{\alpha v} - \theta\right) = 59^\circ.$$

$$\operatorname{Sin}\left(\tan^{-1}\frac{p}{\alpha v} - \theta\right) = .857, \cos\left(\tan^{-1}\frac{p}{\alpha v} - \theta\right) = .515$$

$$\alpha x = \frac{R\,x}{2}\sqrt{\frac{2\,p\,C}{p\,L + \sqrt{R^2 + p^2 L^2}}}$$

$$= \frac{700 \times .17}{2}\sqrt{\frac{2 \times .000001193}{.619 + .643}} = .0819$$

$$\sqrt{\frac{p\,C}{\sqrt{R^2 + p^2 L^2}}} = \sqrt{\frac{.000001193}{.643}} = .001364$$

$$k_1 = 1 + \frac{\alpha^2 x^2}{2} = 1.0033$$

$$k_2 = .082\left(1 + \frac{\alpha^2\,x^2}{6}\right) = .0819\,(1 + .0011) = .0820$$

$$k_1 \sin\frac{p\,x}{v} = .574 \qquad k_1 \cos\frac{p\,x}{v} = .825$$

$$k_2 \sin\frac{p\,x}{v} = .0468 \qquad k_2 \cos\frac{p\,x}{v} = .0673$$

These quantities can now be substituted in the equations 40-43, giving

$$V_0 = 150000\,[(.825)\ (.400) + (.0468)\ (.918)]$$

$$+ \frac{145}{.001364}\,[(.5735)\ (.991) - (.0673)\ (.133)]$$

$$V_{\frac{x}{2}} = 150000\,[(.825)\ (.918) - (.0468)\ (.400)]$$

$$+ \frac{145}{.001364}\,[(.5735)\ (.133) + (.0673)\ (.991)]$$

$$-I_0 = 145\ (.0468)$$

$$+\,150000 \times .001364\,[(.5735)\ (.857) + (.0673)\ (.515)]$$

$$-I_{\frac{\pi}{2}} = 145\ (.825)$$

$$-\,150000 \times .001364\,[(.5735)\ (.515) - (.0673)\ (.857)]$$

Then

$$V_0 = 150000\ (.370) + 145\ (409) = 114{,}900$$

$$V_{\frac{\pi}{2}} = 150000\ (.738) + 145\ (104.7) = 125{,}900$$

$$I_0 = 145\ (.0468) + 150000\ (.000719) = 114.6$$

$$I_{\frac{\pi}{2}} = 145\ (.825) - 150000\ (.000325) = 71.2$$

$$V = 125{,}900 \div \cos \tan^{-1} \frac{114{,}900}{125{,}900}$$

$$= 125{,}900 \div \cos\ (42^\circ,\ 25') = 170{,}600$$

$$I = 114.6 \div \sin \tan^{-1} \frac{114.6}{71.2}$$

$$= 114.6 \div \sin\ (58^\circ,\ 10') = 135.$$

$$\text{Generator Power-Factor} = \cos\ (42^\circ,\ 25' - 58^\circ,\ 10')$$

$$= \cos\ (-\,15^\circ,\ 45') = .963.$$

Since the lag angle is negative the current is leading. The true power at the generator is $V I \times .963 = 22{,}320$ kw. The line energy loss is 2,400 kw. = 10.7%

$$\text{The voltage drop is } \frac{170{,}600 - 150{,}000}{170{,}600} = 12.1\%.$$

Thus the conditions of the generator and line are all determined.

The sign of the various quantities making up V_0, $V_{\frac{\pi}{2}}$, I_0, $I_{\frac{\pi}{2}}$ must be carefully preserved to determine the generator power-factor properly; it should be noted that $\tan^{-1}(-x/y) = 180^\circ - \tan^{-1} x/y$ and that $\cos(-x) = \cos x$, while $\sin(-x) = -\sin x$.

Once the calculation has been made on one particular line for one load, the recalculation for other loads and other voltages is very easy. If the power-factor of the load is the same, only the quantities S and Q need be changed in equations (40) (41) (42) and (43).

If the power-factor of the delivered load is changed, the angles containing θ are of course correspondingly changed, but this does not greatly lengthen the recalculations.

SPLIT CAPACITY FORMULA

For purposes of comparison with the wave formula as here derived, the writer ventures to introduce an approximate formula for calculation of the line quantities, based on the assumptions that one half of the line capacity is concentrated at each end of the line.

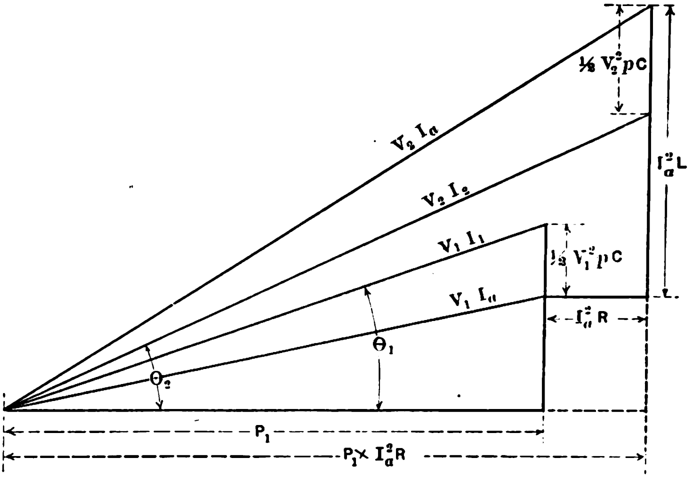

FIG. 2—Relation of power quantities in transmission line

Figure 2 gives the graphical representation of the various power quantities in connection with such a line. Here P_1, V_1, cos θ_1 are the power, voltage, and power-factor of the delivered load. Let I_a be the current in the receiving end in the line itself, and

Let P_2, V_2, I_2, and cos θ_2 be the power, voltage, current and power-factor at the generator. The relations of the *power* quantities is shown in Fig. 2, and the following equations can be written down by inspection:—

$$V_1 I_a = P_1 \div \cos\tan^{-\prime} \frac{P_1 \tan\theta_1 - \dfrac{pCV_1^2}{2}}{P_1} = P_1 \div \cos\theta_1$$

$$V_2 I_a = (P_1 + I_a^2 R) \div \cos\tan^{-\prime} \frac{P_1 \tan\theta_1 - \dfrac{pCV_1^2}{2} + I_a^2 L}{P_1 + I_a^2 R}$$

$$V_2 I_2 = (P_1 + I_a^2 R) \div \cos\tan^{-\prime} \frac{P_1 \tan\theta_1 - \dfrac{pCV_1^2}{2} + I_a^2 L - \dfrac{pCV_2^2}{2}}{P_1 + I_a^2 R}$$

These can be more conveniently written

$$I_a = \frac{P_1}{V_1} \div \cos\tan^{-\prime} \frac{P_1 \tan\theta_1 - \dfrac{pCV_1^2}{2}}{P_1} \tag{46}$$

$$V_2 = \frac{P_1 + I_a^2 R}{I_a} \div \cos\tan^{-\prime} \frac{P_1 \tan\theta_1 - \dfrac{pCV_1^2}{2} + I_a^2 L}{P^1 + I_a^2 R} \tag{47}$$

$$I_2 = \frac{P_1 + I_a^2 R}{V_2} \div \cos\tan^{-\prime} \frac{P_1 \tan\theta_1 - \dfrac{pCV_1^2}{2} + I_a^2 L - \dfrac{pCV_2^2}{2}}{P_1 + I_a^2 R}$$

$$= \frac{P_1 + I_a^2 R}{V_2} \div \cos\theta_2 \tag{48}$$

Generator power factor =

$$\cos\theta_2 = \cos\tan^{-\prime} \frac{P_1 \tan\theta_1 - \dfrac{pCV_1^2}{2} + I_a^2 L - \dfrac{pCV_2^2}{2}}{P_1 + I_a^2 R}$$

These equations are well suited to numerical calculations, especially when several sections of line carrying different loads and having different constants are fed in series.

The difference between the mathematical forms of the wave formula and the split-capacity formula is marked, and it becomes important to know how much difference there may be in the numerical results shown by the two formulas. For purposes of comparison, a considerable number of cases, including some of those calculated by the wave formula in the companion paper, have been calculated by both formulas and the results tabulated in Table I.

Here it is seen that for ordinary commercial cases up to perhaps 150 miles (as cases *A*, *B*, *C*, *D*, *R*, and *S* in Table I) there is only a few tenths of one per cent difference in the results of the two formulas, but that with very long lines the error may reach several per cent in voltage drop, as in (*I*, *K*, *L*, *M*, *P*, *Q*, *T*, *U*, *V*, and *W* of table I).

The error may occur in voltage, energy loss, current or power factor and may be either positive or negative.

Cases *R* and *S*, Table I is of a lead-covered cable of assumed constants; here the discrepancy between the formulas is very small, even though this is an extreme case for a cable transmission. Strictly speaking in this case the leakage of current through the insulation should be considered. The effect of this leakage would here be negligible, however.

It is interesting to note that the line may act to a limited extent as a raising transformer in those cases where the capacity is relatively important. That is, energy given to the line at one voltage may be delivered to the load at a lower voltage and larger current. For example in cases *C*, *P*, and *T*, the total generator current is less than the power component of the load current. In view, however, of the higher generator voltage the *energy* represented by the generator current is greater than that represented by the load current, the excess being the energy line loss.

In applying the split-capacity formula to the case where the load is 0 and only charging current flows, the expression for I_a becomes indeterminate. In this case, however, I_a = the charging current of one-half the line capacity and the formula for I_a need not be used. The rest of the formula does not become indeterminate.

In applying the split-capacity formula to cases where leading current is taken by a synchronous machine at the load end of the line, it must be noted that while this current is leading in the machine it is lagging in the line,—measuring toward the load—and thus has the same effect as lagging load current. With such machines taking leading current, their apparent power is introduced in the formula as part or the whole of the quantity, $p_1 \tan \theta_1$, with the positive sign.

These formulas are all adapted to single-phase calculations. Three-phase lines may be calculated by the well-known rule, that the energy line loss, voltage drop, and power-factor expressed *in percentage* are the same, including effect of capacity current, for a three-phase system as for a single-phase system transmitting one-half the power over any pair of the three-phase wires, which are assumed to be arranged in the usual equilateral triangle grouping. The correctness of this rule is easily seen. With two parallel wires carrying currents, the ohmic drop is the resultant of the drops in the two wires; the inductive e.m.f. depends upon the total number of lines of force between the wires, which will be due to the resultant of the magnetism due to the currents in the two wires individually and the capacity depends upon the potential between wires necessary to produce a given charge on the wires. This potential may be measured by carrying a unit positive charge of electricity from one wire to the other and determining the work done in virtue of the two charges on the two wires. It should be noted that the third wire of a three-phase system, in virtue of its symmetrical position, has no effect either on the lines of force passing between the other two wires, nor upon the total work done in moving a charge between them.

In each of the above cases when the wires carry single-phase currents the effects of the two wires are 180 degrees apart in phase, but are additive in the summation giving the total ohmic and inductive e.m.f., and the work done by a positive charge double that from one wire only.

With three-phase, on the other hand, the two wires have their effects 120 degrees apart instead of 180 degrees so that the resultant effects are not twice but $\sqrt{3}$ times the effect of one wire. So the ratio $\frac{2}{\sqrt{3}}$ exists between these quantities when the wires carry the same current three phase and single phase. To have the same ohmic and inductive e.m.f., which depend upon the current, whether the wires carry single-phase or three-phase current, the single-phase current must be reduced in the ratio $\frac{2}{\sqrt{3}}$, reducing the single-phase power by this amount. But in virtue of the third wire of the three-phase system, it carries $\sqrt{3}$ times as much power as the single-phase having the same current. Therefore, the ratio $\frac{2}{\sqrt{3}} \times \sqrt{3} = 2$ gives the ratio of the power in a single-phase circuit and a three-phase circuit, when in the single-phase circuit and in any two wires of the three-phase circuit, there exists the same resultant ohmic drop total and the same resultant inductive e.m.f. In this case the actual line current in the case of the three-phase will be $\frac{2}{\sqrt{3}}$ times that of the single-phase.

Since the work done by the positive charge in passing between the two wires of the three-phase is only $\frac{\sqrt{3}}{2}$ times that in the single-phase case, the capacity and charging current must be $\frac{2}{\sqrt{3}}$ greater in the three-phase case. Thus the ratio of charging currents in the two circuits is the same as that of the load currents, and the power-factor relations, as well as the voltage relations, must remain the same in the two circuits. Thus the true energy loss in per cent must be the same in the two cases, as already stated.

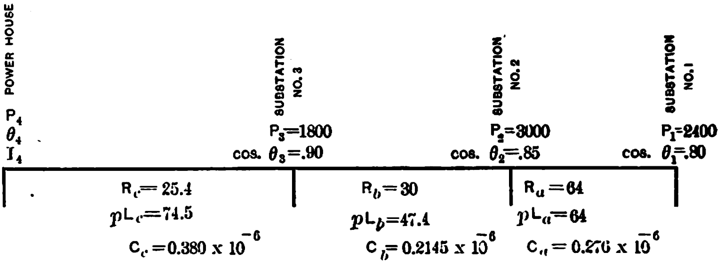
POWER HOUSE
P_4
θ_4
I_4
SUBSTATION NO. 3
$P_3=1800$
cos. $\theta_3=.90$
SUBSTATION NO. 2
$P_2=3000$
cos. $\theta_2=.85$
SUBSTATION NO. 1
$P_1=2400$
cos. $\theta_1=.80$
$R_c=25.4$
$pL_c=74.5$
$C_c=0.380 \times 10^{-6}$
$R_b=30$
$pL_b=47.4$
$C_b=0.2145 \times 10^{-6}$
$R_a=64$
$pL_a=64$
$C_a=0.276 \times 10^{-6}$

FIG. 3—Distribution of loads and line constants in assumed transmission line

This conclusion can be reached by algebraic and trigonometrical methods, but the above demonstration is much simpler and its logic is believed to be sound.

The split-capacity formula is especially convenient where on account of intermediate substations several sections of the line have different constants and different loads; in this case if only the generator quantities are required the calculation can be made as follows: Let there be three stations along a line each receiving power, and let the different sections of the line have different constants all as indicated in Fig. 3. Calculations are made for single phase, assuming half the power transmitted.

	True power quantities	Wattless quantities
Delivered voltage 60,000, 60 cycles		
Power at substation 1	1,200,000	
Wattless component $P_1 \tan \theta_1$		+905,000
Capacity energy at 1, $\frac{p C_a V_1^2}{2}$		− 187,000
	1,200,000	718,000
$I_a = \frac{P_1}{V_1} \div \cos \tan^{-1} \frac{718{,}000}{1{,}200{,}000} = 23.3$		
$I_a^2 R_a =$	35,000	
$I_a^2 L_a =$		35,000
	1,235,000	753,000
$V_2 = 1{,}235{,}000 \div \cos \tan^{-1} \frac{753{,}000}{1{,}235{,}000}$		
$= 62{,}000$		
Capacity energy at 2, $V_2^2 \left(\frac{p C_a}{2} + \frac{p C_b}{2}\right) =$		− 356,000
Power at substation 2	1,500,000	
Wattless at substation 2, $(P_2 \tan \theta_2)$		+930,000
	2,735,000	1,327,000
$I_b = \frac{2{,}735{,}000}{62{,}000} \div \cos \tan^{-1} \frac{1{,}327{,}000}{2{,}735{,}000} = 49$		
$I_b^2 R_b =$	72,000	
		114,000
$I_b L_b =$	2,807,000	1,441,000
$V_3 = \frac{2{,}807{,}000}{49} \div \cos \tan^{-1} \frac{1{,}441{,}000}{2{,}807{,}000}$		
$= 64{,}400$		
Capacity energy at substation 3		
$= V_3^2 \left(\frac{p C_b}{2} + \frac{p C_a}{2}\right) =$		− 451,000
Power at substation 3 $= P_3$	900,000	
Wattless at substation 3 $= P_3 \tan \theta_3$....		+435,000
	3,707,000	1,425,000

$$I_c = \frac{3{,}707{,}000}{64{,}400} \div \cos\tan^{-1}\frac{1{,}425}{3{,}707} = 61.7$$

$I_c^2 R_c =$ 96,500

$I_c L_c =$ .... +283,000

3,804,000 1,708,000

V_4 (at generator)

$$= \frac{3{,}804{,}000}{61.7} \div \cos\tan^{-1}\frac{1{,}708{,}000}{3{,}804{,}000}$$

$$= 67{,}600$$

Capacity energy at generator

$\dfrac{p\, C_c V_4^2}{2}$ .... − 327,000

3,804,000 1,381,000

$$I_4 = \frac{3{,}804{,}000}{67{,}600} \div \cos\tan^{-1}\frac{1{,}381{,}000}{3{,}804{,}000}$$

$$= \frac{3{,}804{,}000}{67{,}600} \div \cos 20^\circ \qquad = \frac{3{,}804{,}000}{67{,}600} \div 0.94 = 59.8$$

$\cos\theta_4$ = power factor = 0.94

For 3-phase at generator.

Power = 7610 kw., KVA = 8100, power factor = 0.94

Drop = 7,600 volts. Energy line loss = 410 kw.

INDUCTION FORMULAS FOR SPLIT CONDUCTORS

The use of split conductors to vary the ratio of capacity and inductance in a transmission line is discussed in the companion paper. An approximate formula for calculating the inductance of a line with split conductors will be derived. Assume a three-phase line of the usual form, but with each conductor split into three parts as shown in Fig. 4; the total inductance between one group of conductors and the neutral point will be determined and then compared with the usual formula for such total inductance, with a single conductor, placed at the center of gravity of the three, at the point Q_1 Fig. 4.

The total inductance sought will be the resultant of the inductances caused by the various currents of the system separately. It will first be proved that the total amount of inductance between two points in space, perpendicular to the line joining these points, due to a long straight wire carrying a current I, is equal to $2 \log_e \dfrac{M}{N}$, where M and N are, respectively, the distances to the more remote and the nearer points. In Fig. 5 let I be the point where the current I passes through the plane of the paper and let S and U be the two points between which induction is to be measured. Let T be any point in the line between the points U and S at a distance x from the base O of a normal to the line $U\,S$ from I. The magnetic field at T is then $\frac{2\,I}{\sqrt{q^2+x^2}}$ when q is the length of the normal, and $\sqrt{q^2+x^2}$ is the distance from I to T. The factor 2 represents the effect of the fact that the wire is very long. The component of this magnetism perpendicular to the line $U\,S$ is

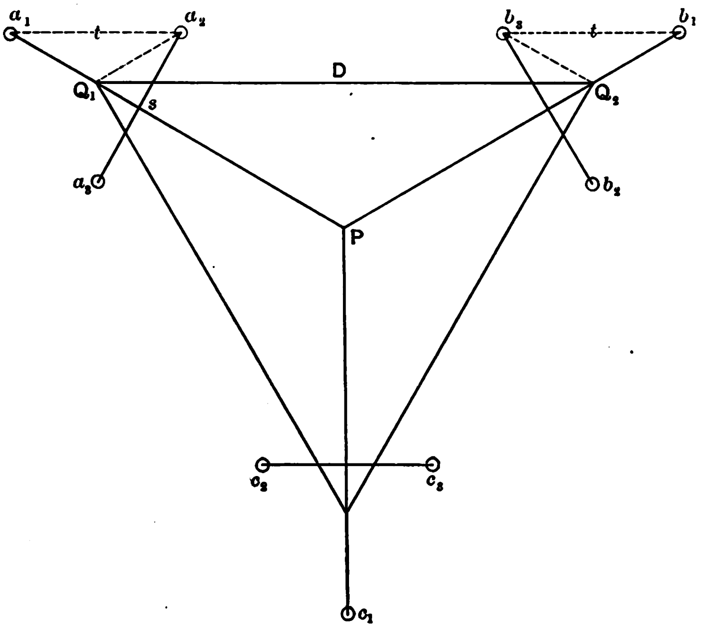

Fig. 4—Arrangement of three-part split conductors for three-phase line

$$\frac{2\,I}{\sqrt{q^2+x^2}} \cdot \frac{x}{\sqrt{q^2+x^2}} = \frac{2\,I\,x}{q^2+x^2}.$$

The total flux of magnetism resolved perpendicular to $U\,S$ between points U and S will be

$$I \int \frac{2\,x}{q^2+x^2} = I \log\,(q^2+x^2) \Bigg|_{O\,S}^{O\,U} = 2\,I \log \frac{M}{N}.$$

From considerations of symmetry it is evident that at times when current in the a group is a maximum, at which times the current in the b and c groups are equal, the resultant magnetism at all points along the line a_1, P, Fig. 4, due to a_1, a_2, a_3 will be perpendicular to this line. It is further evident that the maximum magnetic field between the points s and the point P will be a maximum, when the current in the a group of conductors is a maximum. The value of I in the a group will then be $I \sin 90°$. At this time the current in the b group will be $I \sin (90° + 120°) = -\sin 30° = -\frac{1}{2}$ and the current in the c group will be $I \sin (90° + 240°) = \sin -30° = -\frac{1}{2}$. Furthermore the current is rising in the b group at this instant and falling in the c group. Thus the resultant effect of the b and c group on the magnetism between S and P is not changing at this time, showing that the resultant of the three groups is at a maximum as already stated.

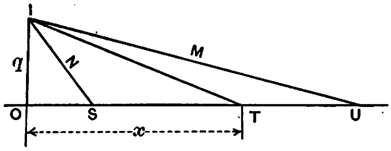

FIG. 5—Diagram of summation of magnetic flux

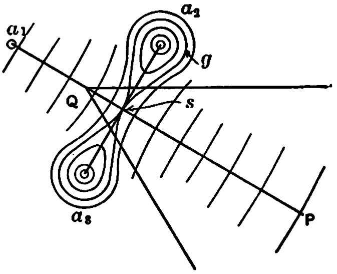

FIG. 6.—Distribution of magnetism due to the currents in conductors a_2 and a_3 of Fig. 4

Again since the currents in the b and c groups are negative when the current in the a group is a maximum, their effect on the magnetism cutting the line $S P$ is added to that of the a group.

The form of the lines of force due to the currents in a_2 and a_3 only is shown in Fig. 6. The lines of force included between a_2 and P may be considered in two parts, that outside the line of force marked g, which can easily be measured along the line $s P$, and the part inside this line of force which can easily be measured along the line $s\ a_3$.

The total magnetism linked between conductor a_2 and P is the same as between either a_3 or a_1 and P. This is evident for a_3

from conditions of symmetry, but is strictly true of a_1 only when its ohmic resistance is 0. Any greater number of lines between a_1 and P than between a_2 and P will cause in the outer wire a greater counter electromotive force, which will reduce the current in a_1, since a_1 and a_2 are in parallel at both ends, and will increase the current in a_2 and a_3 until the resultant magnetism between a_1 and a_2 is O, the effects of current in all groups of conductors being considered. Any resistance in the conductors a_1, a_2, and a_3 will, however, tend to resist this division of current. The resistance effect will be small in large conductors such as would be considered in actual transmission problems. The conclusion is that the current in a_2 or a_3 is greater than one third of the total current. Let k be this corrective increment, that is, the current in $a_2 = I/3\ (1+k)$, I being the total current for one group of conductors.

The various components of the maximum resultant magnetism due to the currents in the various conductors can now be determined.

The portion of the magnetism due to the current in a_2 cutting the line $s\,P$ perpendicular thereto is

$$\frac{2\,I\,(1+k)}{3}\log\frac{M}{N},\ \text{as above.}$$

$$=\frac{2\,I\,(1+k)}{3}\log\frac{\sqrt{\left(\frac{D}{\sqrt{3}}-\frac{t}{2\sqrt{3}}\right)^2+\left(\frac{t}{2}\right)^2}}{\frac{t}{2}}$$

which, in view of the proposition proved above

$$=\frac{2\,I\,(1+k)}{3}\log\frac{\sqrt{\frac{D^2-Dt+t^2}{3}}}{\frac{t}{2}}=$$

$$=\frac{I\,(1+k)}{3}\log\left(\frac{4}{3}\cdot\frac{D^2-Dt}{t^2}\right)\ \text{approx.}$$

But the current in a_3 causes this same amount of magnetism on the line $s\,P$, and that due to both a_2 and a_3 between s and P is

$$\frac{2\,I\,(1+k)}{3}\log\left(\frac{4}{3}\cdot\frac{D^2-Dt}{t^2}\right)\ \text{approx.}$$

The magnetism inside of the line of force g due to the current in a_2 will cut the line $a_2\,s$ perpendicularly and equals

$$\frac{2\,I\,(1+k)}{3}\left(\log\frac{\frac{t}{2}}{\rho}+\frac{1}{4}\right)$$

where the term

$$\frac{2\,I\,(1+k)}{3}\cdot\frac{1}{4}$$

is the inductance within the wire itself and where ρ = the radius of the conductor. Similarly the magnetism due to the current in a_3 between a_2 and s is

$$\frac{2\,I\,(1+k)}{3}\log\frac{t}{\frac{t}{2}}=\frac{2\,I\,(1+k)}{3}\log 2$$

Therefore the magnetism due to a_2 and a_3 between a_2 and s =

$$\frac{2\,I\,(1+k)}{3}\left(\log\frac{\frac{t}{2}}{\rho}-\log 2+\frac{1}{4}\right)=\frac{2\,I\,(1+k)}{3}\left(\log\frac{t}{4\,\rho}+\frac{1}{4}\right)$$

since the effect of a_3 along the line $a_2\,s$ is opposite to that of a_3.

The magnetism produced by the current in a_1 between a_2 and P will be

$$\frac{2\,I\,(1-2k)}{3}\log\frac{\frac{D}{\sqrt{3}}+\frac{t}{\sqrt{3}}}{t}=\frac{2\,I\,(1-2\,k)}{3}\log\frac{D+t}{\sqrt{3}\,t}$$

since the lines of force due to a_1 are circles about a_1.

The effect of the group b may be taken to be the same as though the three conductors were concentrated at the point Q_2. The magnetism between s and P due to the c group will be the same as the b group at this instant of time when the current in the a group is a maximum. The effect of the two groups between a_2 and P is

$$2\,I\log\frac{\sqrt{\left(\frac{D}{2}\right)^2+\left(\frac{\sqrt{3}\,D}{2}-\frac{t}{2\sqrt{3}}\right)^2}}{\frac{D}{\sqrt{3}}}\quad\text{approx.}$$

$$=I\log 3\text{ approx.}$$

Summing all these components of the magnetism:

Total magnetism =

$$\frac{2I(1+k)}{3}\left[\log\left(\frac{4}{3}\cdot\frac{D^2-Dt}{t^2}\right)+\log\frac{t}{4r}+\frac{1}{4}\right]$$

$$+\frac{2I(1-2k)}{3}\log\frac{D+t}{\sqrt{3}\,t}+I\log 3,\ \text{approx.}$$

$$=\frac{2I}{3}\left[(1+k)\left\{\log\frac{4}{3}\,\frac{D^2}{t^2}+\log\frac{t}{4r}\right\}\right.$$

$$\left.+(1-2k)\log\frac{D}{\sqrt{3}\,t}+3\log\sqrt{3}+\frac{1+k}{4}\right]\ \text{approx.}$$

$$=\frac{2I}{3}\left[(1+k)\log\frac{D^2}{rt}+(1-2k)\log\frac{D}{t}+\frac{1+k}{4}\right]\text{approx.}$$

$$=\frac{2I}{3}\left[(1+k)\left(\log\frac{D}{r}+\frac{1}{4}\right)+2\log\frac{D}{t}\right]\text{approx.}\qquad(49)$$

Then the inductance $= L$

$$=\frac{2}{3}\left[(1+k)\left(\log\frac{D}{r}+\frac{1}{4}\right)+2\log\frac{D}{t}\right]$$

These logarithms are natural logs to the base ε.

For a three-phase line without the split conductors, the inductance from one wire to the point P would be

$$2\log\frac{D}{r}+\frac{1}{2}\qquad(50)$$

So that the ratio of these two quantities (49) and (50) represents the change in the inductance due to the splitting of the conductors.

The capacity of the system with split conductors will be increased in substantially the same ratio that the inductance is decreased. The capacity can be determined by finding the work done against static charges on the several wires in moving a unit positive charge, from a_2 to P, for example:

As this work will integrate in exactly the same form as the inductance above (neglecting the inductance within the wire itself) the potential for a given charge between wires will be reduced by splitting the conductors in the same ratio that the inductance was reduced. But the capacity of the circuit is inversely proportional to the potential existing between wires for a given charge, so that the capacity is increased as the inductance is decreased.

There remains the determination of the quantity k. Referring to Fig. 4 the total flux between a_1 and a_2 or between a_1 and a_3 will be the same. This can be calculated by the methods already used.

The magnetism due to a_2 and a_3 between a_1 and s will be

$$\frac{4\,I\,(1+k)}{3}\log\frac{t}{\frac{t}{2}} = \frac{4\,I\,(1+k)}{3}\log 2$$

$$= \frac{2\,I\,(1+k)}{3}\log 2^2$$

The magnetism between s and a_2 due to a_2 and a_3 as before =

$$\frac{2\,I\,(1+k)}{3}\log\frac{t}{4\,r}+\frac{I\,(1+k)}{6}$$

Therefore the total magnetism between a_1 and a_2 due to a_2 and a_3 will be

$$\frac{2\,I\,(1+k)}{3}\log\frac{t}{r}+\frac{I\,(1+k)}{6}$$

The magnetism between a_1 and a_2 due to a_1 =

$$-\frac{2\,I\,(1-2\,k)}{3}\log\frac{t}{r}-\frac{I\,(1-2\,k)}{6}$$

The sum of these values

$$=2\,I\,k\log\frac{t}{r}+\frac{k\,I}{2}$$

$$=2\,I\,k\left(\log\frac{t}{r}+\frac{1}{4}\right)$$

The magnetism between a_1 and a_2 due to the b and c groups which this must balance will be

$$4\,I \log \frac{\sqrt{\left(\frac{D}{2}\right)^2 + \left(\frac{\sqrt{3}\,D}{2} + \frac{t}{\sqrt{3}}\right)^2}}{\sqrt{\left(\frac{D}{2}\right)^2 + \left(\frac{\sqrt{3}\,D}{2} - \frac{t}{2\sqrt{3}}\right)^2}}$$

$$= 2\,I \log \frac{D^2 + Dt + \frac{t^2}{3}}{D^2 - \frac{D\,t}{2} + \frac{t^2}{12}}$$

$$= 2\,I \log \left(1 + \frac{3}{2}\;\frac{t}{D} \right) \quad \text{approx.}$$

That is

$$2\,I\,k\,(\log \frac{t}{r} + \frac{1}{4}) = 2\,I \log \left(1 + \frac{3}{2}\;\frac{t}{D}\right)$$

and

$$k = \frac{\log \left(1 + \frac{3}{2}\,\frac{t}{D}\right)}{\log \frac{t}{r} + \frac{1}{4}} \quad \text{approx.} \qquad (51)$$

which completes the formula for the inductances of the split conductor, having three parts arranged as shown in Fig. 4.

In calculations of three-phase circuits with split conductors by the equivalent single-phase circuit, the ratio of inductances and capacities determined above should be used.

In case the conductor be split into two parts instead of three as above, the following formula can be deduced by the same methods.

Inductance between a_2 and P = $\log \frac{D}{\sqrt{3}\,t} \cdot \frac{D}{r} + \frac{1}{4}$, assuming that the two parts of the split conductor lie symmetrically on opposite sides of the line $s\,P$.

Other formulæ can be easily derived for other arrangements of the wires of the two or three-part combinations or for single-phase circuits. The spiral arrangement of the split conductors will have little effect on the inductance as long as the distances between the centers of gravity of the groups are the same.

This completes the new formulas utilized in the companion paper. It is believed that these, especially the wave and split-capacity formulas will be found especially convenient and serviceable by transmission engineers.

A paper to be presented at the 26th annual convention of the American Institute of Electrical Engineers, Frontenac, N. Y., June 28, 1909.

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(Subject to final revision for the Transactions.)

THE RESISTANCE AND REACTANCE OF ARMORED CABLES

BY J. B. WHITEHEAD

It has been asserted frequently that no form of iron protective covering is permissible for single conductors carrying alternating currents. Experience and simple calculation show this assertion to be well founded with regard to even the thinnest walls, if such walls form a completely closed magnetic circuit about the conductor. In a recent single-phase railway installation it was necessary to carry the trolley circuit across a drawbridge and the nature of the traffic through the draw rendered it advisable to armor the cables, several of which were to be installed for reserve and emergency. Obviously, the use of single-conductor, steel-armored cables was permissible if the reactance and losses in the armor were not prohibitive. There being an apparent absence of data on the subject, and some opinion adverse to the use of such cables, the values of reactance were calculated as explained below. The results showed that even at 60 cycles, and with outgoing and return cables placed close together, the reactance would not be serious; and the subsequent measurements indicate that in cables as manufactured the effect is considerably less than the calculated value, so that for purposes similar to that mentioned the use of the cables is entirely practical.

Calculation. The usual cable consists of a central stranded conductor, surrounded by rubber or paper insulation, covered by tape, lead, jute, and armor in the order named. The armor consists of a number of wires spiralled around the cable; the number of armor wires varies somewhat with the size of cable but is not usually less than 20. The pitch of the spiral is from 5 to 10 times the diameter of the cable, being fixed by the size of armor wire and the requirement to cover the entire outer surface. The exact expression for the inductance in the armor wires is too unwieldly for direct evaluation. A close approximation to its value may be had by neglecting the spiral, by assuming that the intensity of magnetic force is uniform through the armor and equal to the value at the center of the section of an armor wire, and by assuming that the lines of magnetic intensity are circles concentric about the center of the main conductor.

It is obvious that any increase in the inductance due to the armor will take place almost entirely in the region near the circle passing through the lines of contact between the armor wires. This is borne out by the form of integral which is involved, which shows that 0.8 of the total induction is within an arc of 10 degrees on each side the point of contact, and indicates that the above assumptions yield results only a few per cent greater than the exact value. The problem then resolves itself into a determination of the reluctance of a closed magnetic circuit formed by a number of iron wires placed side by side on the circumference of a circle, the magnetic field being at right angles with the length of the wires. The magnetic field is circular and of uniform intensity in the space occupied by the wires. The approximate calculation is further simplified without serious error if the circle of armor wires be considered as laid out side by side in the plane of a uniform magnetic field.

Consider the reluctance of an elementary portion of the magnetic circuit at a distance x from the line passing through all the points of contact, of a width dx, and length equal to the diameter of the armor wire. The length of path in iron is $2\sqrt{r^2 - x^2}$, and the length in air is $2\,(r - \sqrt{r^2 - x^2})$, r being the radius of the armor wire cross-section. The total reluctance per unit length of cable of the circular element of thickness dx is then

$$R = \frac{2\,n}{d\,x}\left(\frac{r^2 - x^2}{\mu} + r - \sqrt{r^2 - x^2}\right)$$

in which n is the number of armor wires and μ the permeability. The error in neglecting the curvature of the circle of contacts is from 1 to 2 per cent for 20 to 30 armor wires.

The total flux in the armor alone is

$$\Phi_i = \frac{4\,\pi\,i}{10\,n} \cdot \tfrac{1}{2} \int_{-r}^{+r} \frac{dx}{r + a\,\sqrt{r^2 - x^2}}$$

$$= \frac{0.4\,\pi\,i}{n} \cdot \frac{1}{a} \left\{ \frac{\pi}{2} - \frac{2}{\sqrt{1 - a^2}} \tan^{-1} \left(\frac{1 - a}{1 + a} \right) \right\},$$

in which

$$a = \frac{1 - \mu}{\mu}$$

For $\mu = 50,\ \Phi_i = 13.8\ \frac{0.4\,\pi\,i}{n}$

$$\mu = 300,\ \Phi_i = 36.7\ \frac{0.4\,\mu\,i}{n}$$

If there were no armor wire the total magnetic induction in the corresponding air space would be equal to

$$\frac{0.4\,\pi\,i}{n};$$

consequently the presence of the armor increases the induction in the space occupied by it from 14 to 36 times, according to the value of μ.

The effect of the flux in the armor on the total inductance of the cable will depend on the radius of the central conductor and the distance between it and the return conductor; that is, on the proportion of the total field of force which is occupied by the armor. The data of one of the cables on which measurements were made are as follows:

Single conductor 0 B. & S. gauge; stranded $\frac{8}{32}$ in. of paper, $\frac{1}{8}$ in. of lead, and a jute bedding about $\frac{1}{8}$ in. thick, armored with No. 10 (B. W. G.) steel wires.

Diameter over strand	373	mils.
" over paper insulation	873	"
Diameter over lead sheath	1123	"
Outside diameter, approximate	1500	"

The values of the inductance of this cable per mile of conductor, at different distances, d, between the outer surfaces of parallel cables, assuming the permeability of the armor to be 1, and applying the formula

$$L = \frac{161}{10^3} \left\{ 2 \log \frac{D - r}{r} + \tfrac{1}{2} \right\},$$

d = distance between centers of cables are as follows:

$d = 0$, $L = 0.71$ millihenry
$d = 2$ in., $L = 1.01$ millihenrys
$d = 6$ in., $L = 1.26$ "
$d = 12$ in., $L = 1.45$ "

The value of L for the space inside the armor is 0.632. Consequently the difference, 0.078, between 0.71 and 0.632 is the proportion which is increased by the factors 14 to 36 mentioned above. Calling this factor k, the values of L with armor wires in contact over the entire circumference are got by adding 0.078 $(k - 1)$ to the values given above. For $k = 36$ the values of L are increased by the armor 4.4, 3.4, 2.9, and 2.7 times respectively for the distances of separation given above, and for 6 ft. separation the factor is 2.2. That is, depending on the distance of separation the reactance of the usual single-conductor, steel-armored cable may be from two to four times as great as the reactance of the same cable without steel armor. Obviously the reactance constitutes no objection to the use of such cables in moderate lengths.

The losses in the armor are not subject to simple calculation. As already stated, about 80 per cent of the total induction in the armor is within an arc of 10 degrees on each side of point of contact of two adjacent wires. For $\mu = 300$ this means an average value of the induction B equal to 166 H within a wall from 0.03 to 0.05 in. thick. At 100 amperes the value of H in the armor of the type of cable under discussion is about 10. It is evident that the resulting losses would not rise to any great value. It is also evident that the assumption that the armor wires are all in contact throughout their length will not be true of the manufactured product. Since the induction in the armor will be greatly decreased for any appreciable air-gap between the individual wires, the reactance and losses should fall below the approximate values as calculated. This conclusion was borne out by the following measurements.

Single-conductor, iron-armored cable. The description of this cable has been already given. The measurements were made on two lengths each 51 ft. long, at different distances apart, with frequencies of 25 and 60 cycles and various values of current. The quantities measured were current, impedance, resistance, and power. The instruments employed were a voltmeter with a range of 0.5 to 3.5 volts and a scale which could be read to 0.005 volt, an electrodynamometer, and a wattmeter. The wattmeter was connected in the 110-volt primary circuit of a special transformer which gave low secondary voltages. The primary current of this transformer was also measured. The net loss in the cable as given in the accompanying table is the wattmeter reading minus the aggregate of the iron and copper losses in the transformer and the copper loss in the leads to the cable. Separate determinations of these values were made at each reading, and the actual or dead resistance—resistance with direct current flowing—measured after each alternating-current reading. The results are given in Table I.

The increase in the impedance with current and with distance between cables is evident but not great. At 60 cycles it varies from 2.2 times the dead resistance, at 67 amperes with the cables close together, to 2.8 times the resistance at 90 amperes with 12 in. between cables. The effective resistance as calculated from the watts lost in the cable is given in column 9 and the effective reactance in column 10. The decrease in effective resistance and the increase in effective reactance with increasing separation is noticeable at 60 cycles, but not important at 25 cycles. At the lower frequency, owing to the saturation of the transformer, the accuracy of the figures for the losses is somewhat impaired. This is reflected in the value of the reactance which is the square root of the difference between two squares of approximately equal value. The order of magnitude, however, is sufficiently indicated.

The reactance per mile of two cables 12 in. apart, as measured at 60 cycles and 90 amperes, is 2.13 ohms; the value calculated as previously explained is 2.94; at 25 cycles the values are 1.80 and 1.23, respectively. The figures for other distances of separation show similar differences, and indicate the measured values to be about 70 per cent of those calculated for the ideal case. As already stated, this is accounted for by the fact that the armor wires are not in contact at all points.

The effective resistance increases with the current density but varies very little with the distance of separation. The value in the cable here investigated increased at 60 cycles and a current density of 1 ampere per 1000 circular mils, to about twice the dead resistance.

TABLE I.

SINGLE-CONDUCTOR CABLE WITH IRON ARMOR.

Two parallel lengths, 51 ft. long each. Conductor No. 0 B. & S. Stranded Armor 29 No. 10 B.W.G. Wires.

1 Separation of cables, inches	2 Amperes	3 Volts	4 Impedance	5 Resistance	6 Gross watts	7 Trans. loss watts	8 Net loss in cable watts	9 Effective Resistance	10 Effective Reactance
	Frequency 60 cycles.								
0	67.2	1.50	0.0223	0.0104	245	160	85	0.0188	0.012
	75.4	1.75	0.0232	0.0104	305	198	107	0.0188	0.0135
	88	2.14	0.0242	0.0105	415	265	150	0.0199	0.0144
2	60.8	1.37	0.0225	0.0102	197	135	62	0.0167	0.0151
	76.28	1.86	0.0244	0.0104	315	208	107	0.0184	0.016
	87.4	2.22	0.0254	0.0103	418	261	157	0.0205	0.0156
6	60.6	1.45	0.0239	0.0103	197	137	60	0.0165	0.0173
	76.25	1.95	0.0255	0.0103	316	212	104	0.0179	0.0181
	86.7	2.31	0.0267	0.0101	411	269	142	0.0189	0.0188
12	59.8	1.49	0.0249	0.0105	196	137	59	0.1064	0.0187
	68.5	1.8	0.0263	0.0104	257	178	79	0.0168	0.020
	89.4	2.53	0.0283	0.0104	447	289	158	0.0192	0.021
	Frequency 25 cycles.								
0	68.7	1.05	0.0153	0.0103	245	173	72	0.1152	0.002
	74.3	1.65	0.0157	0.0103	285	202	83	0.0150	0.003
	84.0	1.375	0.0164	0.0103	381	268	113	0.016	0.003
2	69.6	1.085	0.0156	0.0103	246	175	71	0.0146	0.005
	75.6	1.205	0.0159	0.0102	302	213	89	0.0155	0.004
	83.6	1.375	0.0164	0.0103	371	263	108	0.0155	0.005
6	68.3	1.075	0.0157	0.0103	241	173	68	0.0146	0.005
	75.4	1.220	0.0161	0.0102	294	209	85	0.0150	0.006
	85.8	1.48	0.0172	0.0103	417	296	121	0.0164	0.005
12	70.3	1.17	0.0166	0.0104	258	185	73	0.0147	0.007
	75.5	1.275	0.0169	0.0104	313	220	93	0.0163	0.004
	84.1	1.475	0.0175	0.0104	390	279	111	0.0157	0.008

The effect on the impedance of connecting the lead sheathing at both ends and also connecting the iron armor at both ends, with 12 in. separation, is shown in Table II. It is noticeable that the impedance is reduced by each of these secondary circuits. The increase in impedance with increasing current is less marked, however, indicating the low value of reactance resulting from the presence of the closed secondary circuits. In the same table several values of impedance are given for the case of the return current in the lead sheath. A small value of reactance is indicated at 60 cycles, about one-fifth the value of the dead resistance, assuming the effective resistance to be no greater than the dead resistance. At 25 cycles the difference between impedance and dead resistance is so small as to approach the limits of accuracy to which the instruments could be read.

TABLE II.

Two Single-Conductor Cables with Iron Armor, 12 in. Apart.
Lead sheathings connected at both ends.

60 cycles.				25 cycles.			
Current	Volts	Imped.	Resist.	Current	Volts	Imped.	Resist.
67.5	1.62	0.0240	0.0103	....	....	....	....
77.0	1.89	0.0245	0.0103	80.5	1.375	0.0171	0.0104
84.7	2.1	0.0248	0.0103	90.2	1.59	0.0176	....
Both Sheathings and Armors Connected at Both Ends.							
72.5	1.57	0.0216	0.0105	....	....	....	....
82.7	1.817	0.0219	....	82.1	1.351	0.0164	....
88.6	1.945	0.0219	....	93.7	1.57	0.0167	0.0106
One Cable, with Lead Sheath as Return.							
82.0	1.54	0.0188	0.0185	73.1	1.365	0.0187	0.0187
87.6	1.645	0.0188	0.0186	78.7	1.48	0.0188	0.0188
93.0	1.775	0.0191	0.0187	82.0	1.54	0.0188	0.0188

Single-conductor, copper-armored cable. A series of measurements were made on two 48-ft. lengths of cable similar in all respects to that with steel armor, except that the armor consisted of 24 No. 8 B. & S. hard-drawn copper wires. The impedance was measured at different current densities and with different separations of the cables, with the copper armor connected and disconnected at the ends. The impedance was also measured for a return circuit through the armor wire. The results are given in Table III.

TABLE III.

Single-Conductor Cables with Copper Armor.

	Armor Open				Armor Connected at ends.			
Separation	Cur.	Volts	Imped.	Resist.	Cur.	Volts	Imped.	Resist.
60 cycles.								
0	84.7	0.92	0.0108	0.0092	87.8	0.98	0.0111	0.0092
	91.8	1.01	0.011	0.0092	....	....	....	....
2 in.	84.0	1.00	0.0119	0.0093	82.6	1.03	0.0124	0.0093
	87.7	1.05	0.0120	0.0094	....	....	....	....
6 in.	80.0	1.055	0.0132	0.0094	77.5	1.06	0.0137	0.0094
	86.4	1.152	0.0133	0.0094	84.1	1.16	0.0138	0.0094
12 in.	77.1	1.11	0.0144	0.0096				
	84.6	1.24	0.0146	0.0096				
25 cycles.								
0	98.8	0.83	0.0095	0.0093	89.0	0.845	0.0095	0.0091
2 in.	87.5	0.855	0.0098	0.0094	86.2	0.86	0.0099	0.0093
6 in.	86.9	0.897	0.0103	0.0094	87.2	0.92	0.0105	0.0094
12 in.	85.1	0.905	0.0106	0.0097	83.5	0.935	0.0112	0.0096

One cable length with return through copper armor.

60 cycles.				25 cycles.			
Current	Bolts	Imped.	Resist.	Current	Volts	Imped.	Resist
71.6	0.500	0.0070	0.0065	65.0	0.42	0.0064	....
83.6	0.595	0.0071	0.0067	71.6	0.48	0.0067	0.0066
89.5	0.6530	0.0070	0.0068	73.5	0.50	0.0068	....

At 60 cycles and 12 in. separation the reactance per mile of double conductor, as calculated from the measured values of impedance and resistance at 82 amperes is 1.19 ohms. As calculated from the value of L given by the formula previously stated, the value is 1.196. This indicates a negligible eddy-current loss in the copper armor. The readings with the armors of the two cables connected at both ends indicate a small increase in the effective resistance.

Table IV gives the impedance values for a double-conductor, steel-armored cable. The conductors were similar to those in the single-conductor cables and spaced at 0.873 in. between centres. The diameter over the lead sheath was 2.025 in. and the armor consisted of 38 No. 18 B.W.G. steel wires. At 91 amperes and 60 cycles the impedance per mile, as measured, was 1.144 ohms. The value as calculated by means of the formula for L and the measured value of the dead resistance was 1.071 ohms. The close agreement of measured and calculated values of reactance in the case of the cables with copper armor, indicate that the increase in impedance of the double-conductor cable is due to increase in the effective resistance. This increase is probably due to eddy currents in the lead sheath rather than to any effect of the steel armor.

TABLE IV.

Double-Conductor Cable with Iron Armor.

60 cycles				25 cycles.			
Current	Volts	Imped.	Resist.	Current	Volts	Imped.	Resist.
84.6	0.968	0.0113	0.0101	82.9	0.860	0.0104	0.0101
88.5	1.020	0.115	0.0101	86.0	0.905	0.0105	0.0102
91.0	1.050	0.0115	0.0101				

Conclusions. 1. Theoretically the reactance of the usual type of single-conductor, iron-armored power cable may be from 2 to 4.5 times that of unarmored cable, depending on the distance to return conductor; the factor increases with decreasing distance.

2. In cables as manufactured the reactance is about 0.7 of the maximum theoretical value.

3. The effective resistance as measured varies little with the distance to return conductor and is about 1.6 and 2 times the

dead resistance at 25 and 60 cycles, respectively, and a current density of 1 ampere per 1000 circular mils.

4. The impedance for distances under 12 in. is about 3 times the dead resistance at 60 cycles and 1.7 to 2 times the dead resistance at 25 cycles. With the sheathing and the armor grounded at both ends the impedance is somewhat lessened and is largely of the nature of resistance.

5. The impedance of a double-conductor, iron-armored cable, with conductors located 0.873 in. apart between centers, and at the current density given above, is about 7 per cent greater at 60 cycles and 3 per cent greater at 25 cycles than the calculated value. The increase is in effective resistance, due to eddy currents in the lead sheathing.

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REDUCTION IN CAPACITY OF POLYPHASE MOTORS DUE TO UNBALANCING IN VOLTAGE

BY S. B. CHARTERS, JR. AND W. A. HILLEBRAND

It is well-known that polyphase motors of both induction and synchronous types overheat when supplied from circuits in which the ideal conditions of voltage balance and phase angle are not maintained. In order to determine definitely the performance under other than ideal conditions, and to ascertain the points at which overheating commences, a series of tests was run under varying conditions of voltage unbalance, unsymmetrical angular relations between phases, and combinations of these two.

The authors have not attempted to analyze the performance under these conditions in any but the most elementary manner, and are able only to present the results of their tests with such comment as will bring out the essential features developed.

The equipment for the test consisted initially of a laboratory motor built by one of the leading companies; this was a 7.5 h.p., six-phase motor, capable of operating either as a two-phase or three-phase machine. The terminals of all phases were brought to an external connecting block or tablet and all inter-connections were made there. On this motor the first series of tests were made in order to determine the essential features of the performance, and were then followed by characteristic runs on several different commercial machines. The principal data of the machines tested are given in Table I.

Power was supplied by a two-phase 60-kw. inductor alternator, with voltage regulators in each phase, through two 10-kw. multitap transformers. Three phases were obtained from the two-phase supply by means of the Scott connection. By the use of the voltage regulators and various taps on the transformers any desired degree of unbalance could be obtained. When operating two-phase, the phase angle of one of the applied pressures was shifted by combining with it pressure from a quadrature source, as shown in Fig. 1. This connection also unbalanced the voltage as well, but, when desired, the two voltages could be brought to equality by means of regulators at the generator.

From any three-phase star or delta connection wherein the vector sum of the electromotive forces is zero, it is impossible to obtain unbalanced voltages without a shift of the phase angle as well, so that in the three-phase runs no attempt was made to separate these factors.

TABLE I.

Machine	h.p.	No. of phases	Rotor	Voltage	Frequency	Connection
Laboratory model as induction motor........	7½	2	squirrel cage	190	60	
Laboratory model as induction motor........	7½	3	squirrel cage	127	60	delta
Laboratory model as synchronous motor...	7½	2		310	60	
Commercial induction motor...............	10	2	squirrel cage	200	60	
Commercial induction motor...............	5	3	squirrel cage	220	60	Y
Commercial induction motor...............	2	3	squirrel cage	110	60	delta(?)
Commercial induction motor...............	5	3	Wound rotor with internal starting resistance	110	60	delta (?)

One set of instruments, especially calibrated for this test, was used throughout. Instruments were applied to one phase at a time and then shifted to the next, two or more sets of readings being taken from each phase, the second serving as a check and to insure that conditions did not change during the time the readings were being taken.

The motors were loaded by belting to a separately excited direct-current generator.

The operating limit of a motor, as determined by the temperature rise in any one phase, is reached when the current in that phase has attained its normal full-load value. Throughout these tests the motor was loaded under varying conditions of voltage unbalance and phase shift until the normal rated current was reached in one phase, when the output at that point was determined. Curves were then plotted showing the relation between the output at this point and the percentage of voltage unbalance and irregularity of phase difference. The voltage in the high phase was maintained at normal value throughout. The per cent. of voltage unbalance is defined as the difference between maximum and minimum voltages divided by the maximum, whether operating two-phase or three-phase.

In the test with the laboratory model, delta connected, it was found, on comparing the currents in the motor winding and in the lead wires, that with a condition of unbalance represented by two voltages high and of approximate equality and one voltage low, the current in the lead wire and that in the motor itself reached normal value at the same time, regardless of the percentage of unbalance. This fact is made use of in operating the two 110-volt, three-phase motors, for, not knowing whether they were connected Y or delta, we had no other means of determining when the current in the motor winding had reached normal value. Accordingly the motors were assumed to be delta connected and operated with two voltages high and one low, and, on the basis of the performance of the laboratory model, it was assumed that when normal current was reached in one of the lead wires one phase of the motor winding was also

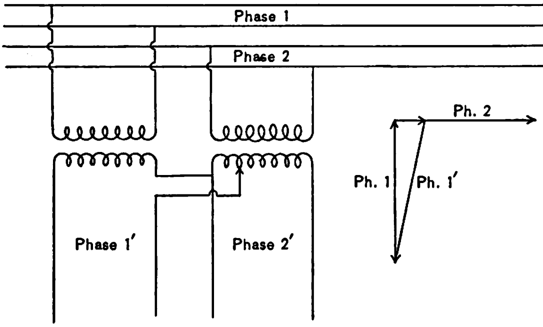

Fig. 1

carrying normal rated current. As indicated by Fig. 2, the motor would probably not behave very differently under any other condition of unbalance.

That the performance is practically independent of the nature of the voltage unbalancing, whether this takes the form of two voltages equal and the other higher or lower, or of all three at different values, is well brought out in Fig. 2, which shows the results of tests made upon a three-phase, Y-connected motor under all three conditions. This point, however, we do not regard as settled, because with our laboratory set delta connected, an appreciable difference has been observed between the performance with one voltage high and two low, and that with two high and one low, the latter being somewhat the worse condition. The difference, however, is not enough to alter the results materially, and we have not been able to determine as yet whether it is due to the fact that this is a special machine or whether it is more or less common to all motors.

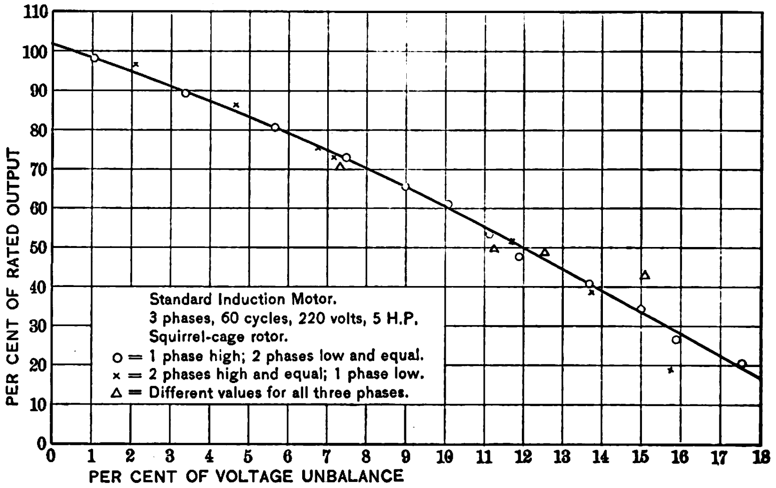

FIG. 2

The extent to which reduction in capacity is caused by voltage unbalancing is strikingly brought out by Figs. 2, 3 and 4. We wish particularly to call attention to the practical identity of the curve of Fig. 2 and curves *C* and *D* in Fig. 3, which represent the performance of three commercial motors differing in type, voltage or rating, in which a voltage unbalance of 10 per cent caused a reduction in capacity of 40 per cent.

The worst performance of all is shown in Fig. 4, which is that of a 2-h.p. three-phase 110-volt motor in which an unbalance of 10 per cent caused a reduction in capacity of. 54 per cent or 44 per cent, according to which curve is used. On the name plate 13.7 amperes were given as the full-load current, whereas our test, with balanced voltage, showed 11.1 amperes at the rated output of 2 h. p.

Voltage unbalance, however, is not the only factor to be considered in the case of two-phase motors, for departure of the supply voltages from the quadrature relation, or phase shift, has an even greater effect. By measurement it was found that our generator gave practically true quadrature phases under all conditions of unbalance, the difference being less than 0.5 degree, so that the results from voltage unbalance alone are not complicated by phase shift.

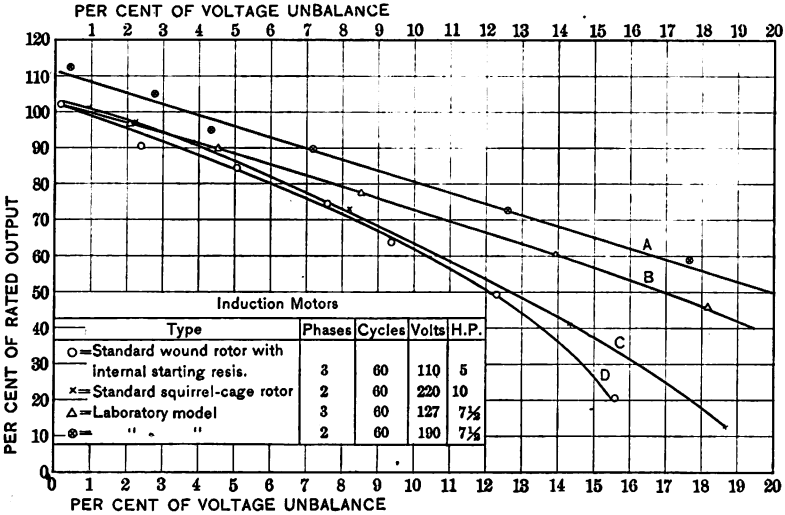

FIG. 3

The extent to which phase shift causes reduction in capacity is shown in Fig. 5, where in the one commercial motor tested a departure of 5 degrees from the quadrature relation caused a loss in output of 26 per cent.

Next to the extent to which reduction in capacity is caused by voltage unbalance or phase shift, the most significant fact is that the reduction seems to vary with either irregularity approximately according to a straight line law. With a combination of the two, however, in the case of a two-phase motor, the effect seems to be cumulative and certainly worse than the sum of the two individual results. This is indicated by the results given in Table II.

Cases 1, 2 and 3 were the laboratory model operated as a two-phase motor. Cases 4 and 5 were the commercial 10-h.p. two-phase motor, and furnish evidence along the same line, though the result is not so striking for the reason that, at the particular values used, the effect due to phase shift greatly exceeded that due to voltage unbalance, which therefore contributed a much smaller proportion to the combined result.

TABLE II.

Case	Unbalance alone		Phase shift alone		Unbalance and shift combined			Sum of *A* and *B*
	Per cent unbalance	*A* Per cent reduction	Degrees shift	*B* Per cent reduction	Per cent unbalance	Degrees shift	Per cent reduction	
1	5.38	16.2	10° 1′	20	5.38	10° 1′	50.2	36.2
2	9.05	27	14° 9′	30	9.05	14° 9′	72.7	57
3	8.16	24.3	21° 37′	42	8 16	21° 37′	98.7	66.3
4	2.1	3	5° 27′	31	2.1	5° 27′	36.9	34
5	4.38	10.5	6° 49′	38	4.38	6° 49′	52.4	48 5

Figs. 3 and 5 bring out the fact that the performance of the laboratory model with either voltage unbalance or phase shift is much superior to that of the commercial motors. For instance, with 10 per cent voltage unbalance its capacity was reduced 30 per cent as against 40 per cent for three commercial motors, and with a 5-degree phase shift the figures are 10 per cent for the laboratory model and 26 per cent for the commercial motor. By reference to Fig. 6 it will be seen that the efficiency of the laboratory model is about 3 per cent lower than the average of the efficiencies of the four standard motors. With greater proportions of unbalance and phase shift the difference in favor of the special machine is even greater. This shows in convincing manner how design may affect performance under other than ideal conditions.

It should be borne in mind that in all the foregoing tests the voltages recorded are those at the motor when operating with full-load current in at least one phase, and that they do not represent line conditions, no account having been taken of transformer regulation or voltage drop in the lead wires.

The effect of transformer regulation is to improve the conditions at the motor, for our experiments showed that the high phase always furnished the heaviest current, which would mean a greater reduction in the voltage of that phase, tending to bring the motor voltages to equality. In the three-phase motor the effect of transformer regulation is not so easy to foresee, because one phase can not be altered without affecting both of the others. However, it appears from observations made to determine this point that the three-phase case does not differ materially from the two-phase, in the tendency of transformer regulation to improve conditions of unbalance at the motor. The results of these observations are given in Table III.

TABLE III.

No load			Full load in one phase		
Voltage in high phase	Voltage in low phase	Per cent unbalance	Voltage in high phase	Voltage in low phase	Per cent unbalance
115.42	91.22	20.95	109.45	91.67	16.52
115.17	97.17	15.61	110.75	97.02	12.4
113.6	100.25	11.76	109.47	99.05	9.52
115.65	108.65	4.475	110.32	105.37	4.48

In this run the primary voltage was held constant under both no-load and full-load conditions.

These figures must be understood as applying to a particular case, because the inherent regulation of our transformers, as connected, was poor. However, the results may be doubtless taken as indicating the general effect of transformer regulation. It is the line unbalance at no load which is responsible for the performance of the motor, so that this performance will be largely dependent on local conditions. If the motor is operated from its own individual transformers the regulating effect will be much greater than if it is only one of a large number of motors supplied from transformers of large capacity on which the effect of any individual motor will not be appreciable. Therefore, in a large shop driven by polyphase motors supplied from a common set of transformers, if unbalance exists the performance of the motors will be much better when all are running than when only a few are in operation.

This improvement due to transformer regulation means a general lowering of voltage, most of which, however, takes place in the high phase. The general lowering of voltage means a reduction in the capacity of the motor, but this is more than counter-balanced by the improvement in the condition of unbalance which enables each phase to approach more nearly its proper share of the power. For example, in our laboratory set a 20 per cent unbalance at the motor with normal voltage in the high phase means a reduction in capacity of about 65 per cent. Assuming a transformer regulation which would give 15 per cent unbalance at the motor, the reduction in capacity would be only 43 per cent, provided the voltage in the high phase could be maintained at normal. If this 15 per cent unbalance at the motor is accompanied by a 10 per cent reduction in the voltage of the high phase, with a corresponding reduction in the other phases, the additional reduction in capacity is only

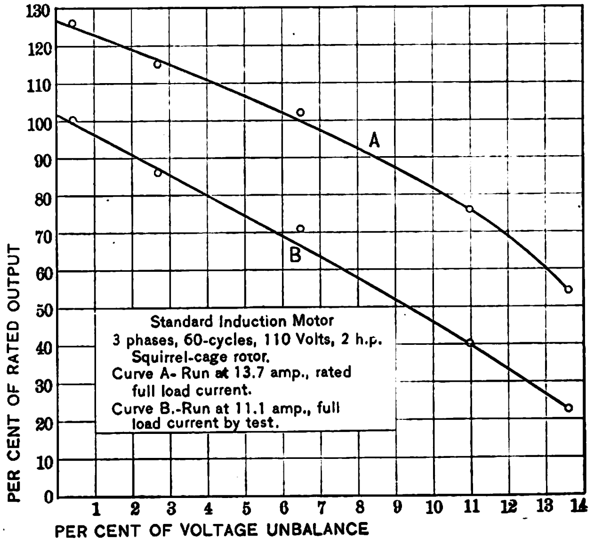

FIG. 4

6 per cent, as shown by curve *C*, Fig. 7, giving a total of 50 per cent reduction for a combined 15 per cent unbalance and 10 per cent reduction below normal of the voltage in the high phase, as compared with 65 per cent reduction in capacity for 20 per cent unbalance, normal voltage being maintained in the high phase.

Curve *C*, Fig. 7, shows the reduction in output or torque in the laboratory set, operating three phase and delta connected, as the voltage is lowered at a uniform unbalance of 14.8 per cent, current being maintained at normal value in the high phase. This unbalance of 14.8 per cent is the ratio of the difference between maximum and minimum voltages divided by the maximum voltage and not by normal voltage. Curve *A*, Fig. 7, shows results obtained with the same motor under conditions of balanced voltage, and curve *B* those obtained under conditions of balanced voltage but with a different motor.

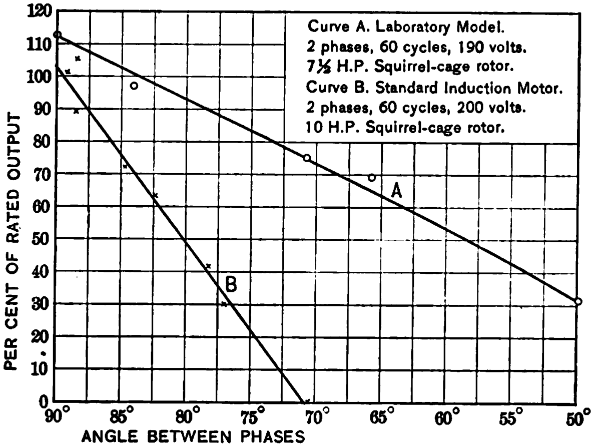

FIG. 5

Curves *A* and *B* would represent the performance due to line drop, with balanced voltage. Curve *C* would approximately represent the performance of a three-phase motor with unbalanced voltage as affected by line drop alone, for the observations recorded in Table IV indicate that with a three-phase motor the line drop does not tend to materially improve the conditions of unbalance.

With the two-phase motor the effect of line drop is similar to that of transformer regulation, improving the conditions of unbalance at the motor, since the higher phase, where reduction is most needed, invariably furnishes the most current.

Curves *A* and *B*, Fig. 7, are of interest in their bearing on the commonly accepted statement that the torque of an induction motor varies as the square of the voltage. This is true provided the slip remains constant. If the slip is allowed to vary and the current held constant, the torque will be found to vary with the first power of the voltage, and this condition is the one usually found in practical operation. The familiar torque equation is

$$Q_p = k \frac{s\, r_2\, E}{r_2^2\ \overline{s x_2}^2} \qquad (1)$$

wherein Q_p = torque per phase.

TABLE IV.

Transformer voltage				Motor voltage				Motor voltage
Intermediate phase	High phase	Low phase	Per cent unbalance	High phase	Low phase	Per cent unbalance	Per cent load	Intermediate phase
112.7	130.0	112.0	13.88	115.95	101.1	12.81	83.6	104.9
102.4	128.45	102.0	20.6	113.95	90.25	20.8	71.8	97.4
127.3	127.35	111.1	12.7	120.05	106.15	11.53	69.3	116.25

k = a constant, depending upon units in which torque is expressed.
r_2 = secondary resistance.
x_2 “ reactance.
E = primary induced e.m.f.
s = slip.

also

$$s = i_2^2 \frac{r_2 k}{Q_p} \qquad (2)$$

wherein i_2 “ secondary current.

Substituting the equivalent of s from equation 2 in equation 1, and reducing,

$$Q_p = k\, i_2 \sqrt{E^2 - \overline{i_2 x_2}^2}$$

Keeping i_2 constant, this equation represents approximately a straight line, as borne out by the results shown in Fig. 7. Holding the primary current constant, the secondary current will also be nearly constant, a slight change being introduced by the decrease in magnetizing current with the drop in pressure, but not enough to materially affect the straight line relation of torque and voltage.

SYNCHRONOUS MOTOR

The test on the synchronous motor was performed in exactly the same manner as with the induction motor except for the fact that the field excitation of the synchronous motor was adjusted at every observation so as to give minimum current in the high phase under the existing conditions.

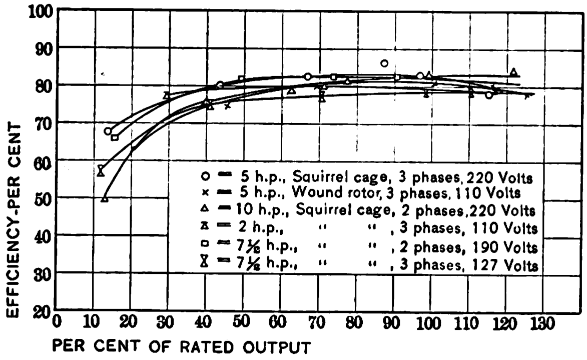

FIG. 6

The results obtained with the synchronous motor are submitted not on account of their quantitative value but because of the indication they afford of the manner in which synchronous motors and converters behave when supplied from unbalanced circuits.

We wish to call attention to the striking similarity between synchronous and induction motor performance in that the reduction in capacity due to either phase shift or voltage unbalance varies in both cases approximately according to a straight line law, and that shift of phase is a much more serious factor than voltage unbalance. See Fig. 8.

The synchronous motor, however, differs materially from the induction motor in its behavior under conditions of combined

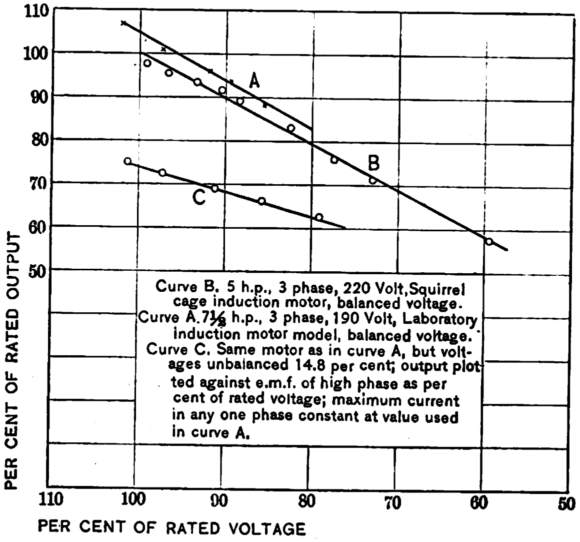
110
100
90
80
70
60
50
A
B
C
Curve B. 5 h.p., 3 phase, 220 Volt, Squirrel cage induction motor, balanced voltage.
Curve A. 7½ h.p., 3 phase, 190 Volt, Laboratory induction motor model, balanced voltage.
Curve C. Same motor as in curve A, but voltages unbalanced 14.8 per cent; output plotted against e.m.f. of high phase as per cent of rated voltage; maximum current in any one phase constant at value used in curve A.
PER CENT OF RATED OUTPUT
110
100
90
80
70
60
50
PER CENT OF RATED VOLTAGE

FIG. 7

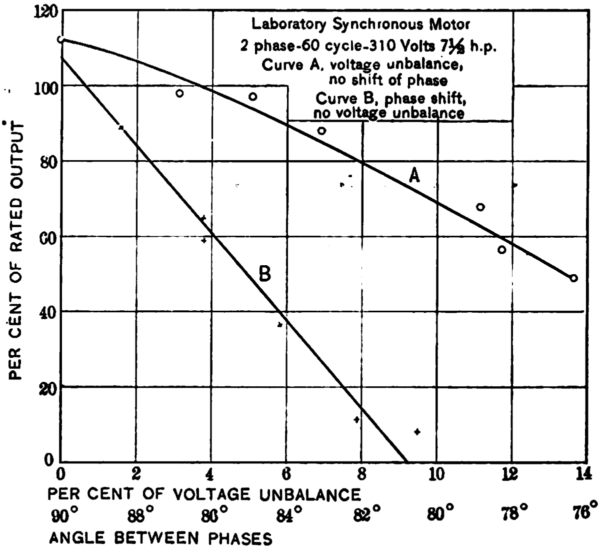
Laboratory Synchronous Motor
2 phase-60 cycle-310 Volts 7½ h.p.
Curve A, voltage unbalance, no shift of phase
Curve B, phase shift, no voltage unbalance
120
100
80
60
40
20
0
A
B
PER CENT OF RATED OUTPUT
0
2
4
6
8
10
12
14
PER CENT OF VOLTAGE UNBALANCE
90°
88°
86°
84°
82°
80°
78°
76°
ANGLE BETWEEN PHASES

FIG. 8

phase shift and voltage unbalance, in that the two effects seem to neutralize one another, and an improved performance results, as shown in table V.

TABLE V.

Synchronous Motor Performance.

Unbalance alone	Reduction in capacity	Phase shift alone; degrees	Reduction in capacity	Sum of reductions	Effect of combined unbalance and phase shift
8.4%	34%	4.0	48%	82%	42%
3.6%	11%	2.1	24%	35%	10%

In general, the effect of voltage unbalancing is to circulate a quadrature current component in one phase. The effect of phase shift is to circulate an in-phase current in both phases, one phase often pumping back into the line. In either case, one phase takes most, if not quite all, of the power. When voltage unbalancing and phase shift exist together, with field excitation adjusted to give equal currents in the two phases, approximately similar conditions exist in the two phases and each is enabled to take more nearly its proper share of the power

SUMMARY AND CONCLUSIONS

Summarized briefly, the results of our tests are the following:

1. Unbalancing of voltage and shift of phase tend to cause serious overheating in polyphase motors.

2. Where it is possible to separate the effects due to phase shift and voltage unbalance, phase shift is found to be relatively of more importance.

3. The reduction in capacity due to either phase shift or voltage unbalance varies with the cause approximately according to a straight line law.

4. In the induction motor the existence of phase shift and voltage unbalance causes a worse performance than would be expected from either irregularity alone, whereas in the synchronous motor the reverse is true.

5. The performance of the induction motor supplied from an unbalanced circuit is materially affected by its design.

6. The commonly accepted statement that the torque of an induction motor varies with the square of the voltage should be

changed to read, "varies directly with the voltage," in order to make it more consistent with conditions of ordinary operation.

The authors hope that this paper will promote further investigation and discussion of the subject of line unbalance, which is continually increasing in importance as transmission lines increase in the amount and variety of service which they furnish.

A paper to be presented at the 26th annual convention of the American Institute of Electrical Engineers, Frontenac, N. Y., June 28, 1909.

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(*Subject to final revision for the Transactions.*)

CALCULATION OF IRON LOSSES IN DYNAMO ELECTRIC MACHINERY

BY I. E. HANSSEN

It is well known that the iron losses in all kinds of electric motors and generators are invariably much greater than those calculated from iron-loss curves, such as are obtained from tests of samples of iron, unless an allowance is made for additional losses.

The causes of this increase in the losses are many and varied. They have been dealt with in detail by various writers, but so far as the writer knows, a simple method for predetermining the total iron loss has never appeared in print. The losses in the different parts of the magnetic circuit will be considered in a general way and the causes of the additional losses will be pointed out. It is hoped that this paper will be of some use to designers in pointing out a method which has been found successful in actual practice after about one and a half years use.

Consider a smooth-core armature of a generator for either direct or alternating current. The paths of the flux are shown in Figs. 1, 2, and 3. It will be noticed that the distribution lacks uniformity more or less, due to the difference in the length of the paths. This lack of uniformity naturally leads to an increase of the losses above what they would be were the distribution uniform.

An allowance must further be made to take care of imperfect insulation between the discs, caused by filing, burrs, and crushing of the insulating material when subjected to pressure, and also for the hardening effect caused by the punching process if the discs are not again annealed.

To prevent the teeth from bulging out, a number of extra heavy discs are usually placed at the ends of the core and next to the ventilating ducts if such are provided. These heavy discs, being from two to three times thicker than the regular ones, will have from four to nine times greater eddy current losses. Sometimes these discs have a higher permeability than the thinner ones, and this will still further increase the losses due to the higher induction which will exist in the thicker discs.

Iron-loss curves of iron samples, as usually made, give the losses taking place when the iron is subjected to an alternating magnetic field. The field in an armature, however, is not an alternating one but is of a rotary nature, probably elliptical. Such a field is generally conceded to cause considerably higher iron losses than the alternating field, provided the density at which the iron is worked does not exceed a certain limit. This limit is reached at about 120,000 c. g. s. lines per square inch. If the density is increased above this value, the loss per unit of iron decreases rapidly. However, such high densities are hardly ever reached in armature cores, except in the teeth, so that there is generally a further allowance to be made, due to the field being a rotating one.

In a smooth-core armature, the foregoing probably covers all the additional iron losses in the machines, provided the armature and field structure are perfectly concentric. If they are not concentric, the gap reluctances will vary with different positions of the armature, the result being that the flux in the field poles and yoke will not have a constant value but will pulsate and thus produce eddy currents in the field structure. *Dr. W. M. Thornton, who first called attention to this fact, cites a case in which this loss amounted to 2300 watts for a 10-kw. generator.

Assuming that the armature and field structure are concentric, the actual iron loss, due to the above-mentioned causes, will be from 25 per cent to 35 per cent greater than calculated from the iron curves for smooth-core armatures.

Toothed armatures. What has just been said about smooth-core armatures applies equally well to the iron back of the slots of toothed armatures, the only difference being that in the latter

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*See Journal of the Institution of Electrical Engineers V-33, page 545.

Figures 1, 2, 3, 4, 5, and 6 are reproduced from the paper by Prof. W. M. Thornton, referred to previously. Figures 7, 8, and 9 are taken from a paper by Hele-Shaw, Hay & Powell, Journal of the Institute of Electrical Engineers, Vol. 37, No. 179.

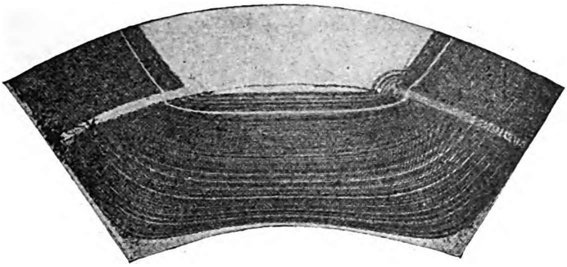

FIG. 1

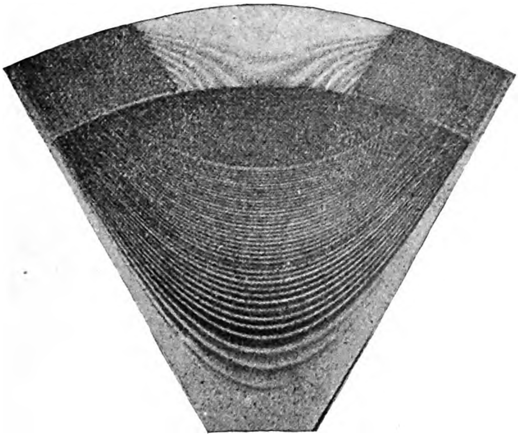

FIG. 2

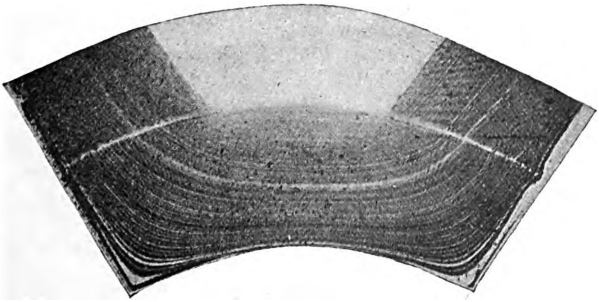

FIG. 3

Stream Lines of Magnetic Induction in Smooth Cores

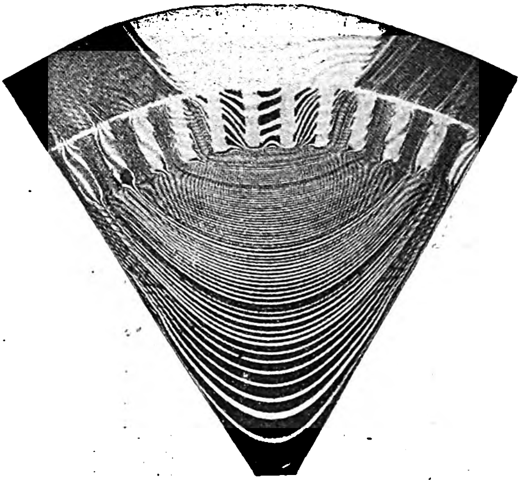

FIG. 4

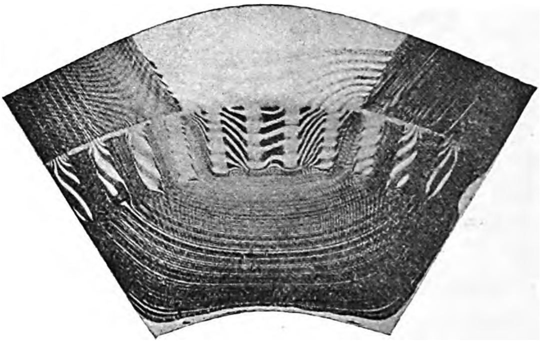

FIG. 5

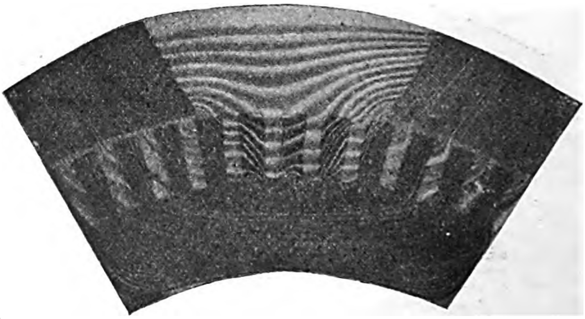

FIG. 6

Lines of Magnetic Induction in Toothed Cores the distribution is less uniform, as an inspection of Figs, 4, 5, and 6 will show. It will be seen that for some distance back of the teeth the density is higher than back of the slots, and of the same order as the density in the teeth. If the iron is nearly saturated, these streamers of higher density appear to continue all the way from pole to pole, as pointed out by Dr. Thornton. It is probable that this phenomena nullifies somewhat the reduction of the iron loss which would otherwise occur when iron subjected to a rotating field is worked above 120,000 lines per square inch.

The writer has found that adding 30 per cent, 35 per cent, and 40 per cent for 25, 40, and 60 cycles, respectively, to the calculated loss in the iron back of the slots, gives very nearly correct results.

Losses in the teeth. In the teeth the percentage increase in the losses due to filing and burrs may become much greater than is the case for the part of the iron already discussed, particularly in high-frequency machines (50 and 60 cycles), in which the eddy currents in the burrs become very marked. Here also we have to allow for the thicker discs next to the ventilating ducts and at the core ends. Furthermore, due to the leakage field, the resultant field is elliptical instead of alternating. An addition of 30 per cent, 60 per cent, and 80 per cent, for 25, 40, and 60 cycles, respectively, has been found to give satisfactory results.

Losses due to slot openings. In addition to the losses already mentioned there are other losses, particularly in machines having wide-open slots, caused by variations in the gap density. In direct-current and synchronous machines, these losses are produced by eddy currents in the pole-shoes, while in induction motors they are caused partly by eddy currents in the tooth-faces and partly by density variations extending throughout the depth of the teeth. Fig. 10 shows roughly the flux distribution in a portion of the gap of a direct-current machine or in a synchronous machine with projecting poles. As will be seen, the density opposite a slot is lower than that opposite a tooth, the result being that the pole-shoe is subjected to the influence of a high-frequency field.

The frequency of this field is $\frac{\text{rev. per min.} \times S}{120}$ cycles per second, S being the number of armature slots.

In an induction motor in which both the primary and second-

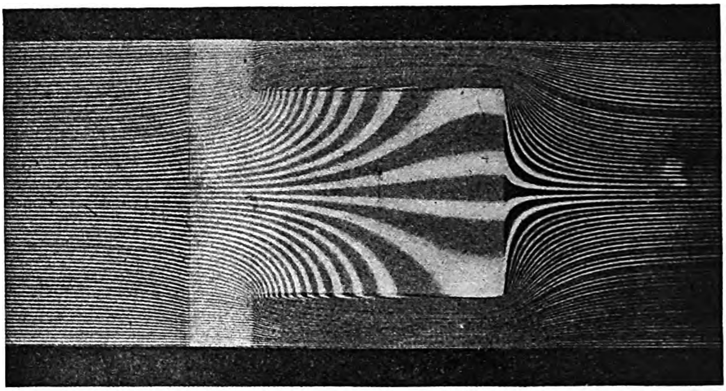

Fig. 9

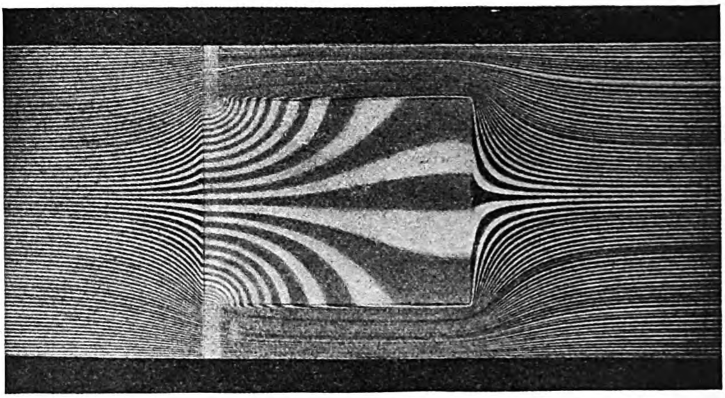

Fig. 8

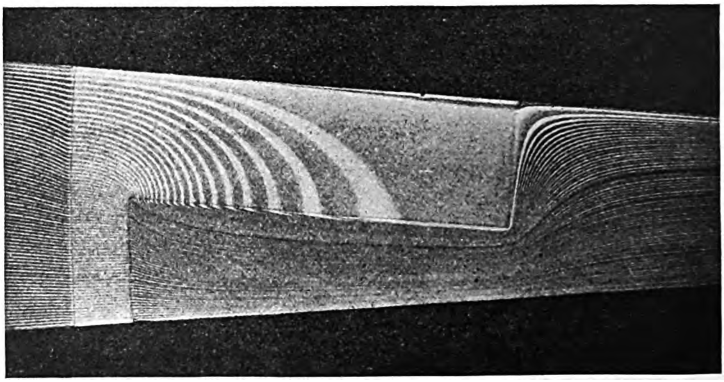

Fig. 7

ary members are slotted, both members will be subjected to these pulsations. However, as the secondary slot openings are generally very small, the losses from this source in the primary iron will as a rule be of no great moment.

The frequency of the pulsations in the secondary member is $\frac{\text{rev. per min.} \times S\,p}{120}$ cycles per second, where $S\,p$ is the number of primary slots, while to obtain the frequency in the primary the number of secondary teeth is substituted for the number of primary teeth in this expression. The amount of variation in density can be calculated quite accurately, but this requires a considerable amount of time, and experience indicates that this refinement is not justified.

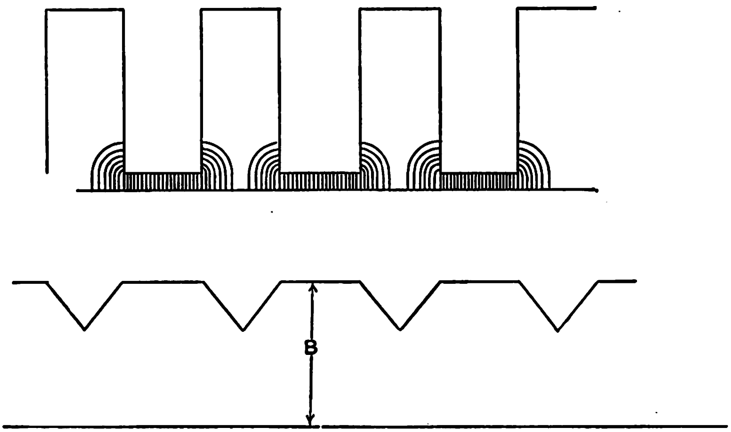

FIG. 10

Within practical limits of slot and gap dimensions, the variation can be said to be roughly proportional to the expression: k/δ

where δ = air-gap.
k = slot opening.

As the losses are caused mainly by eddy currents, while the hysteresis loss is much smaller, the lotal losses from this source will vary nearly as the square of the frequency and probably approximately as $\left(\frac{k}{\delta}\right)^2$. Therefore it should be possible to plot curves of the expression $\frac{B\,k\,s \text{ rev. per min.}}{\delta}$ against watts loss per square inch of iron surface in the air-gap, B being the maximum density in kilolines per square inch of secondary tooth face, fringing being neglected.

In the case of alternating-current machines, in which only a few standard frequencies come into consideration, it is probably more accurate to plot the curves using the expression $\frac{B\,k\,s}{\delta\,p}$ making a curve for each frequency to be used. The necessary data can be obtained by determining the losses in the teeth and in the portion of the core back of the teeth in the manner already explained, deducting the value thus obtained from the iron loss observed on test.

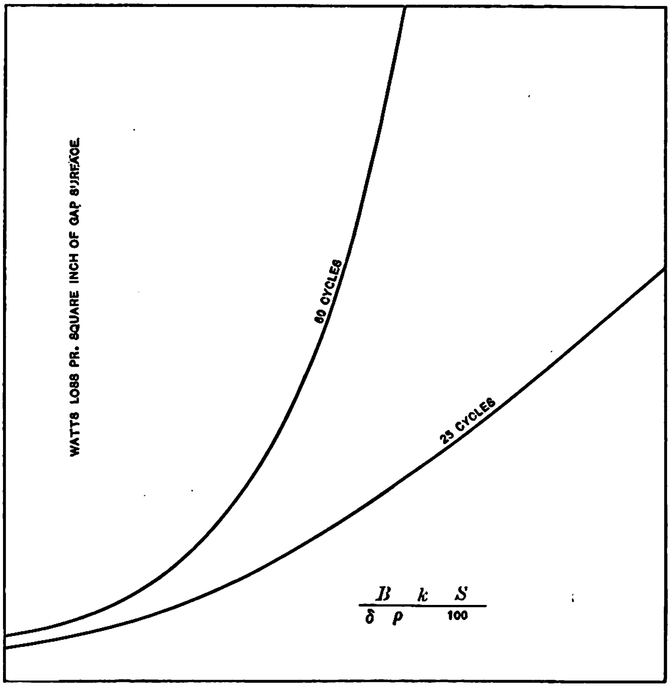

FIG. 11

In direct-current machines and in alternating-current machines having projecting poles, the result will represent the loss in the pole shoes, provided the rotating and stationary parts are concentric.

In machines with distributed field windings and in induction motors, part of the result represents losses in the primary and part in the secondary. It is possible in such a case to separate the two, but it is easier to obtain the necessary data from machines with projecting poles, and in the case of induction motors by choosing machines in which the secondary slot openings are small and the number of secondary slots less than that of the primary.

Curves obtained in this manner have been used by the writer and others with satisfactory results. The general form of such curves is shown by Fig. 11. In obtaining the data for these curves, it is necessary to distinguish between laminated surfaces which are not finished and such as are either ground or turned. A slight cut in the lathe will increase the surface losses about 50 per cent, while grinding may affect them more or less than this, the increase being greater for coarse wheels applied under considerable pressure.

In induction motors in which the air-gap necessarily is very short, wide-open slots are often objectionable, particularly in high-speed machines, as the iron loss due to the slot openings will often equal the losses due to the variations of the main field. This can be easily understood when it is known that for a 60-cycle machine, in which for the primary $\frac{B\,k\,s}{\delta\,P\;100} = 150$, this loss amounts to about 7 watts per square inch of secondary iron surface exposed to the gap.

Moreover, in comparing the running iron loss of an induction motor with the iron loss at standstill, it will in many cases be found that the former exceeds the iron loss at standstill although in the latter case the secondary iron is subjected to the full frequency of the line.

A paper presented at the 26th annual convention of the American Institute of Electrical Engineers, Frontenac, N. Y., June 28, 1909.

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COMPARATIVE COSTS OF 25-CYCLE AND 60-CYCLE ALTERNATORS

BY CARL J. FECHHEIMER

The statement is frequently made that 25-cycle alternators are more expensive than 60-cycle machines built for the same output, speed, voltage, and phase. A considerable difference of opinion exists at the present time as to how much more the low-frequency machine should cost than the corresponding high-frequency machine. When an attempt is made to analyze conditions, by examining the cost records of machines built by a large manufacturing company, one is confronted by a maze of figures which assist but little toward solving the problem. This is not at all surprising when one considers the many changes which have accompanied the rapid development of alternating-current generators. Some machines have a relatively great amount of iron, while others have a relatively great amount of copper; there is considerable difference in the results obtained from the various methods used for ventilating alternators; some are much more liberal as regards heating, or voltage margin, or regulation, than others; the excitation differs appreciably in machines for nearly the same rating; some were built when material and labor were high, etc. In this paper an attempt has been made to eliminate, as far as possible, some of these variables.

In a paper entitled "The Relative Proportions of Copper and Iron in Alternators," read by the writer before the Atlantic City Convention of the Institute in 1908, a method was worked out for determining the value of flux necessary to obtain the cheapest machine. In the appendix, which was subsequently added, the cost of the exciter is brought into the equations, with the view of reducing to a minimum the cost of the entire equipment, including alternator and exciter. In this paper the method employed has been to determine this value of flux for a machine of a given rating, and to use this value of flux for determining the capacity and cost of the exciter, the approximate diameter and length of machine, and the weights and costs of material in each of the principal parts of the alternator, in accordance with the method described in the paper referred to.

A sufficient number of points for plotting curves was worked out for two speeds common to 60-cycle and 25-cycle alternators; namely, 300 and 100 rev. per min. The former speed is intended to apply to water-wheel-driven alternators, and the latter to engine-type alternators. The curves are intended to apply to revolving-field alternators having rectangular poles.

They are further intended to apply to three-phase machines wound for approximately 2300 volts. The high-voltage machines require somewhat lower flux densities in the stator iron, and the necessity of using deeper slots in the stator causes the teeth to become a larger factor of the total stator iron than was allowed for. Moreover, the heating of the stator coils for the same copper loss is considerably greater than in the low-voltage machine. Furthermore, the insulation and the labor required for placing it on the coils becomes a considerable factor in the cost of the alternator.

Allowances were made for each alternator to have an inherent regulation of about 8 and 19 per cent at normal load, and at unity and 85 per cent power-factor respectively; each will be capable of giving its normal voltage at 25 per cent overload in kilowatts at 85 per cent power-factor. The temperature rise of the stator coils will be about 35 degrees cent., when operated at full load for 24 hr., and 50 degrees when operated at 25 per cent overload for 2 hr. following the full-load run, these temperatures being based on 100 per cent power-factor conditions.

A curve was plotted with kilowatts per 100 rev. per min. against the cost of exciters; and from this curve the cost per kilowatt (*pe*) of the exciters could be determined. The exciters were considered to be belted units with a pulley ratio of 3 to 1. This represents about the average condition; for in a large number of plants the exciting current is taken directly from the direct-current bus-bars, in which case no exciter is furnished, while in others, an engine or motor-driven exciter is used.

In the following table, the values assumed for the various constants used are given.

TABLE I.

	100 rev. per min.		300 rev. per min.	
	25 cycles	60 cycles	25 cycles	60 cycles
B_a = Flux density in armature core in kilolines per sq. in.	65	40	68	40
$B_{f.\,r.}$ = Flux density in field ring in kilolines per sq. in.	38 (C.I.)	38 (C.I.)	70 (C.S.)	70 (C.S.)
B_p = Flux density in poles in kilolines per sq. in.	98	93	98	93
k = Distribution factor for stator coils	0.955	0.955	0.955	0.955
K = Ratio of net to gross iron in poles	0.91	0.91	0.91	0.91
K^{I} = Ratio of field ampere-turns per pole required for full field to the armature ampere conductors per pole with full load	1.7	1.8	1.7	1.8
K^{II} = Ratio of tangential dimension of pole to axial length of pole	0.5	0.34	0.65	0.45
K^{III} = Resistivity in micro-ohms, of an inch cube of copper at the temperature of the fields when hot	0.85	0.85	0.85	0.85
K^{IV} = Ratio of axial length of pole to pole pitch	1.	1.5	.75	1.
K^{VI} = Factor by which the product of amperes per sq. in. and ampere conductors per in. should be divided to give the temperature rise in degrees centigrade of armature coils	$3.\mathrm{x}10^4$	$3.5\mathrm{x}10^4$	$3.5\mathrm{x}10^4$	$4\mathrm{x}10^4$
K^{VII} = Ratio of length of armature end connection per coil to pole pitch	3.6	3.6	3.6	3.6
K^{IX} = Ratio of net iron in armature to axial length of pole	0.8	0.8	0.81	0.81
K^{XI} = Coefficient used for determining weight of yoke	1.9	1.9	2.2	1.9
K^{XIII} = Ratio of pole radial height to sq. root of pole tangential dimension	3.1	3.1	3.1	3.1
p_a = Price, in dollars per pound, of armature copper	0.2	0.2	0.2	0.2
p_{ai} = Price, in dollars per pound, of armature active iron	.0325	.0325	0.0325	.0325
p_f = price in dollars per pound of field copper	0.2	0.2	0.2	0.2
$p_{f.\,r.}$ = price in dollars per pound of field ring material	0.0225 to 0.025	0.0225 to 0.025	0.0325	0.0325
p_p = price in dollars per pound of pole iron	0.0215	0.0215	0.0215	0.0215
p_y = price in dollars per pound of yoke iron	0.0225 to 0.025	0.0225 to 0.025	0.0225 to 0.025	0.0225 to 0.025
T = Temperature rise in degrees centigrade, of armature coils	35	35	35	35
o = Pole leakage factor	1.2	1.2	1.2	1.2
σ' = field-ring leakage factor	1.25	1.25	1.25	1.25

The following additions were made for scrap material and parts not included in equations.

TABLE II.

	100 rev. per min.		300 rev. per min.	
	25 cycles	60 cycles	25 cycles	60 cycles
Field copper	2%	2%	2%	2%
Armature copper	10%	10%	10to12%	10to12%
Armature active iron	45%	50%	45to50%	50to60%
Yoke	15%	15%	15%	15%
Poles	25%	25%	25%	25%
Field ring	25%	25%	25%	25%

From an inspection of equation (21) in the paper previously referred to, it will be seen that if the same constants were employed, and the flux per pole varied inversely as the frequency, then the product of field copper weight and excitation would vary inversely as the frequency. The flux per pole is about three times as great in the 25-cycle as in the 60-cycle machine, and as there is a difference in the constants, the product is but about 44 per cent greater in the 25-cycle than in the 60-cycle machine. This is shown in Figs. 1 and 2.

As in the case of the field copper, if the constants were the same for the 25-cycle and 60-cycle alternators and if the flux per pole varied inversely with the frequency, the armature copper would vary inversely with the frequency. As will be seen from Fig. 2, however, the difference is but 63 per cent.

The necessity for using more active iron in the stator of the 25-cycle machine is evident, even though considerably higher densities are used, especially since the flux per pole is about three times as high in the 25-cycle as in the 60-cycle machine. The relative costs are shown in Fig. 3, where a difference of about 35 per cent appears.

The necessity for making the radial height of the pole greater in the 25-cycle than in the 60-cycle alternator, due to the greater number of ampere-turns, makes the weight of the poles for the former considerably greater than the latter. In Fig. 3 this difference will be seen to be about 70 per cent.

Since the internal diameter of the stator of the 25-cycle alternator is less than the 60-cycle, the weight of the yoke will be very nearly the same, even though the axial length and radial depth of laminations are greater, and the greater depth of laminations necessitates a somewhat stiffer construction. This is shown in Fig. 4.

The field ring, while somewhat smaller in diameter for the 25-cycle machine, must be sufficiently greater in section to carry the greater flux per pole. For determining these curves, the assumption has been made that if the field ring is large enough to carry the flux, its cross-sectional area will be of sufficient for mechanical purposes. The material used has been taken to be cast iron for the 100-rev. per min. machines, and cast steel for the 300-rev. per min. machines. From Fig. 4 it will be seen that the field ring is approximately twice as heavy for the 25-cycle as for the 60-cycle machine.

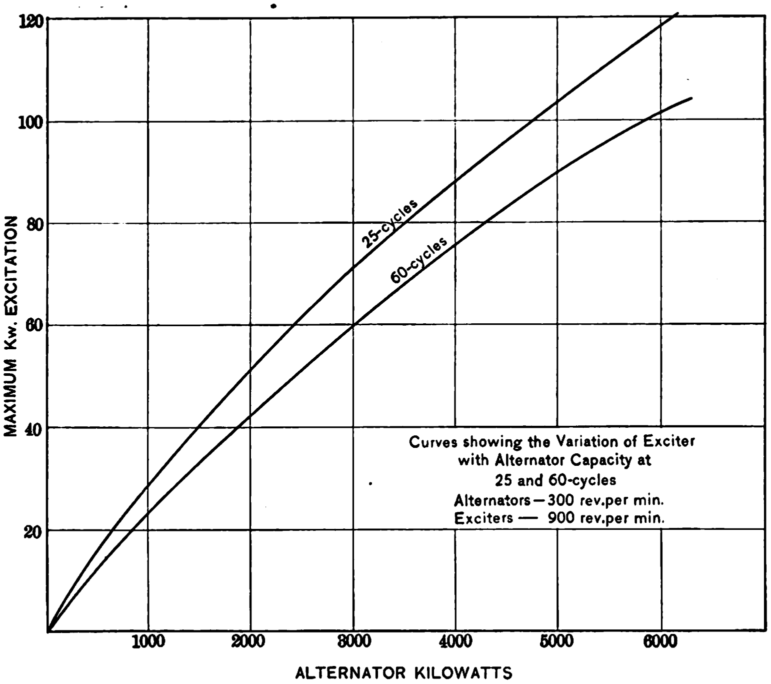


Fig. 1

Figs. 5, 6, and 7 show the comparative weights and costs of the copper and iron in the principal parts of the alternator. The principal parts include the armature and field copper, the armature active iron, the yoke, poles, and field ring.

With the exception of the curves shown in Fig. 7, the curves above described, apply to alternators operating at 300 rev. per min. In Fig. 8, the relative costs of material in the principal parts are shown in the forms of curves for 25 and 60-cycle alternators operating at 100 and 300 rev. per min. It is interesting to note that the principal material in the 25-cycle machine at 300 rev. per min. will cost nearly as much

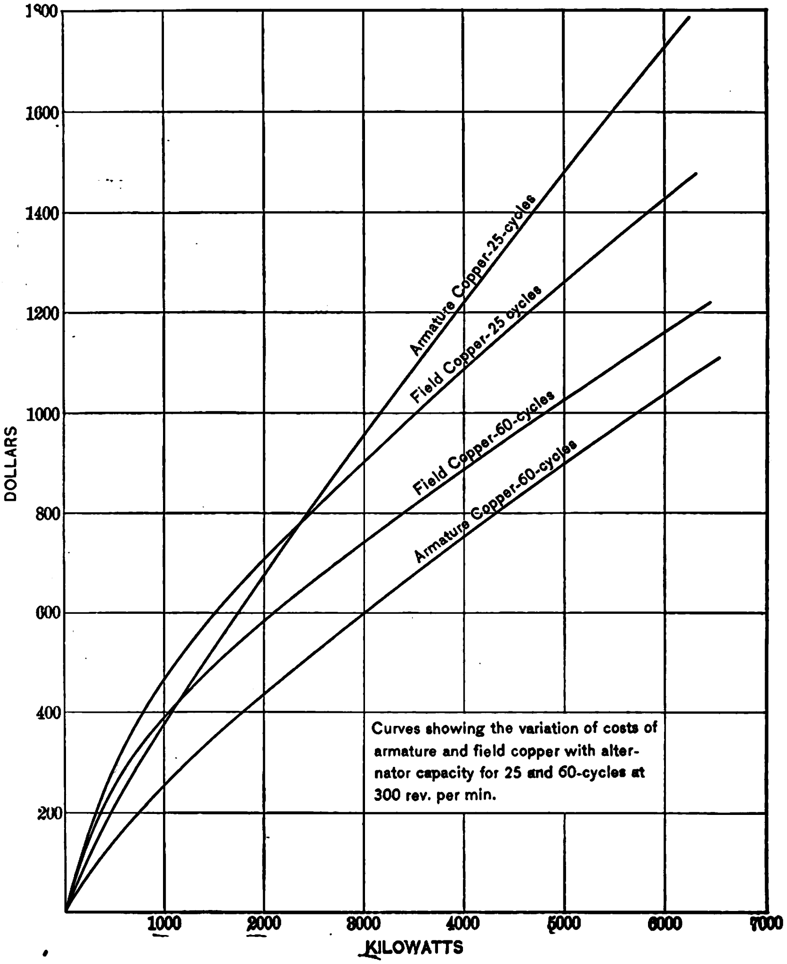


FIG. 2

as the equivalent material in the 60-cycle at 100 rev. per min. Also the cost of the 25-cycle machine at 300 rev. per min. will be about 42 per cent more than the 60-cycle machine, whereas the difference is but 33 per cent at 100 rev. per min. This condition exists, even though the "cubical contents" of the stator (represented by the product of the axial length of pole and the square of the internal diameter of the stator) is slightly less in the 25-cycle machine at 300 rev. per min., and slightly greater at 100 rev. per min., as shown in Fig. 9.

In order to determine the cost of the total material in the alternator, the cost of material in the principal parts was compared with the total cost of material in a number of alternators which had previously been built. In estimating the cost of material in the principal parts of these machines, about the same allowances were made for unavoidable scrap material as those given in Table II, and the prices of the materials were taken to be the same as existed at the time at which the various alternators were built. The ratings of each of the alternators were nearly the same as those for which the estimated curves in this paper are given. None of them was made with heavy rotors

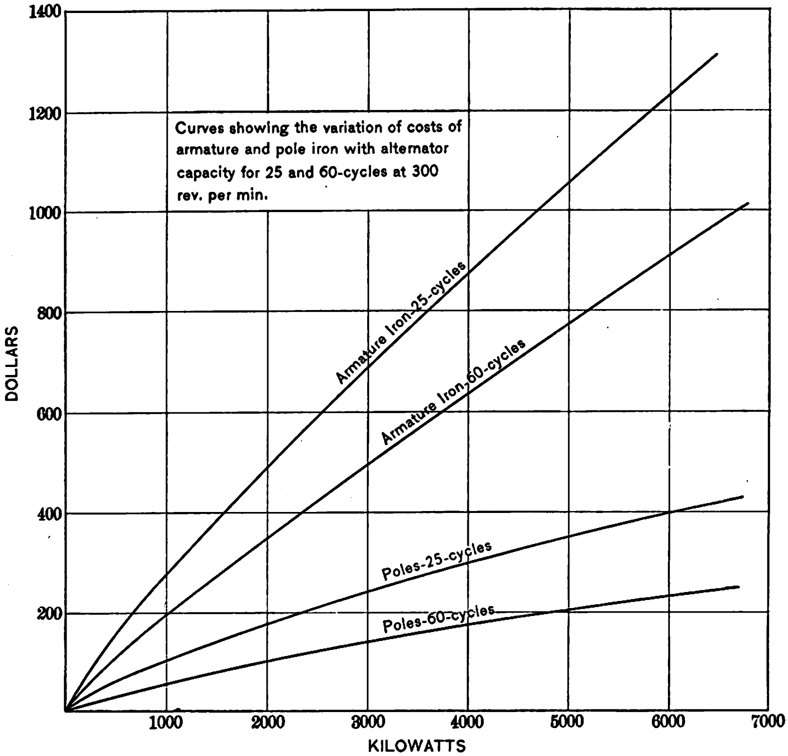


Fig. 3

with expensive material therein, necessitated by high over-speed requirements. The ratio of the cost of total material to material in the principal parts was found to lie between 1.4 and 2, the former applying as a lower limit to the engine type

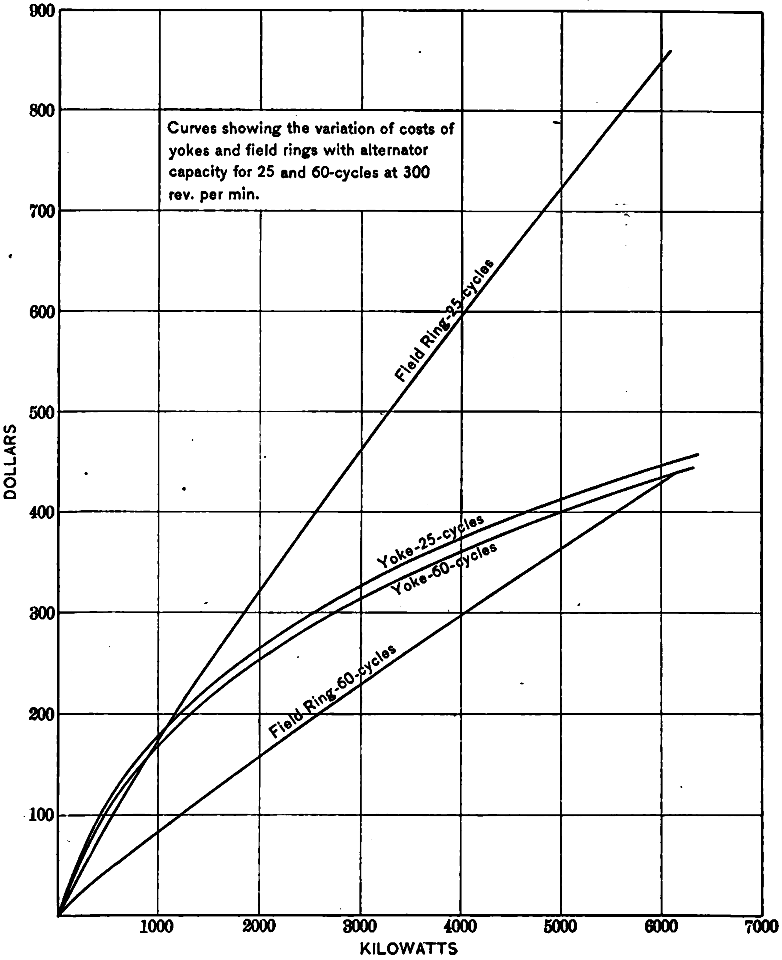


FIG. 4

alternators, and the latter as an upper limit to water-wheel type alternators.

For the purpose of determining the relation which the labor bears to material in the alternator, the ratio of labor to material was plotted against kilowatts per 100 rev. per min. for a large number of 60-cycle and 25-cycle engine and water-wheel-driven alternators which had previously been built. The burden has been omitted in allowing for the labor. Although this is contrary to the usual method of estimating costs, it has been

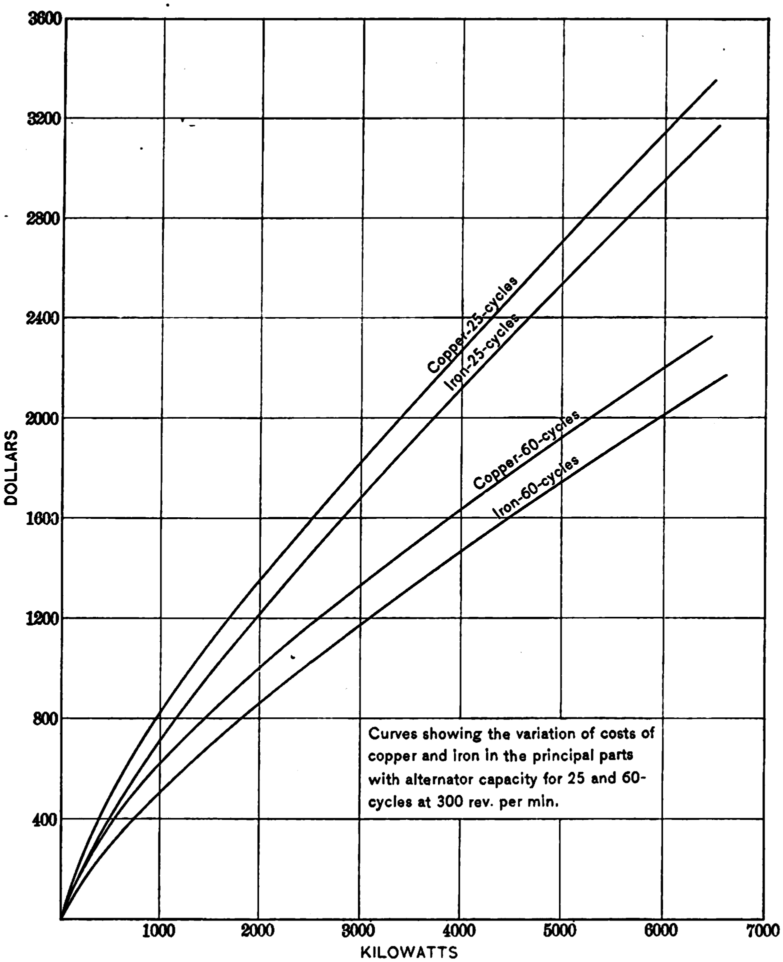


Fig. 5

taken to be nearly correct for an estimate of the character undertaken in this paper; for it is evident that the office expenses and other fixed charges usually included in the burden, are affected little, if any, by the frequency, or even by the size of machine which the factory undertakes to build.

The costs of material previously considered, the material not included in the principal parts, the labor, rheostat, and exciter were added together, giving the actual factory cost of the entire equipment. In Fig. 10 these are plotted as " relative ", rather than " actual " costs, for the great difference in mechanical design of bases, bearings, etc., and the variation in labor, both as regards location and period, would influence the total cost of the equipment considerably; whereas the relative costs would not be greatly altered. This will be more evident when a com-

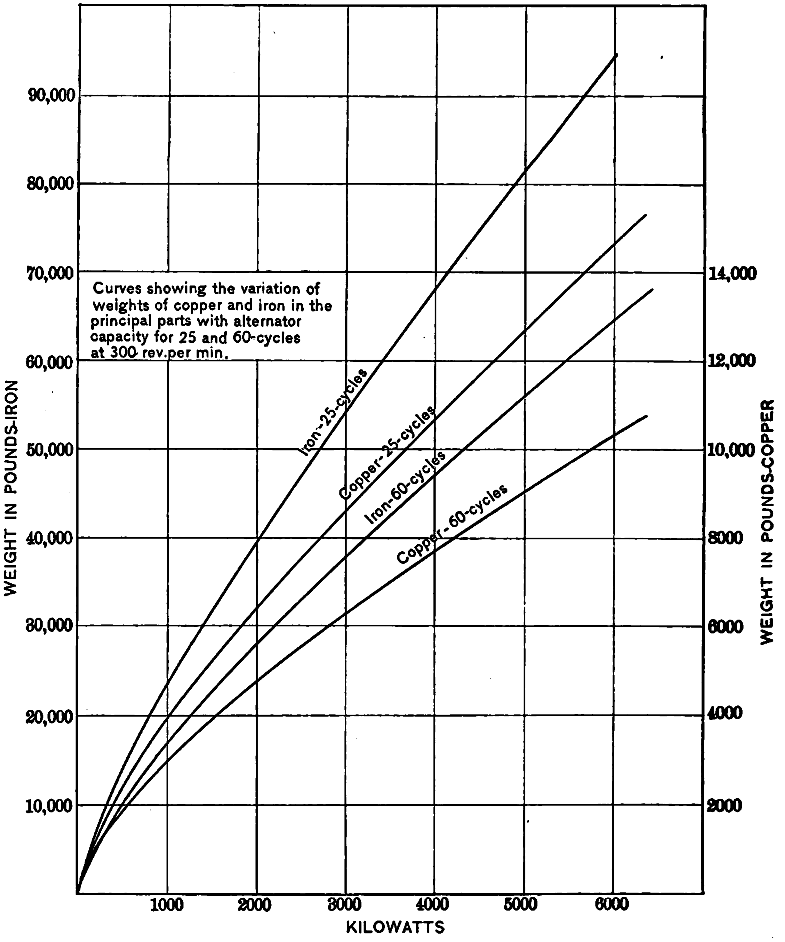


FIG. 6

parison of Figs. 8 and 10 is made; this comparison shows that the costs of the entire equipment and the material in the principal parts are nearly the same for the 25-cycle and 60-cycle machines operating at the same speed.

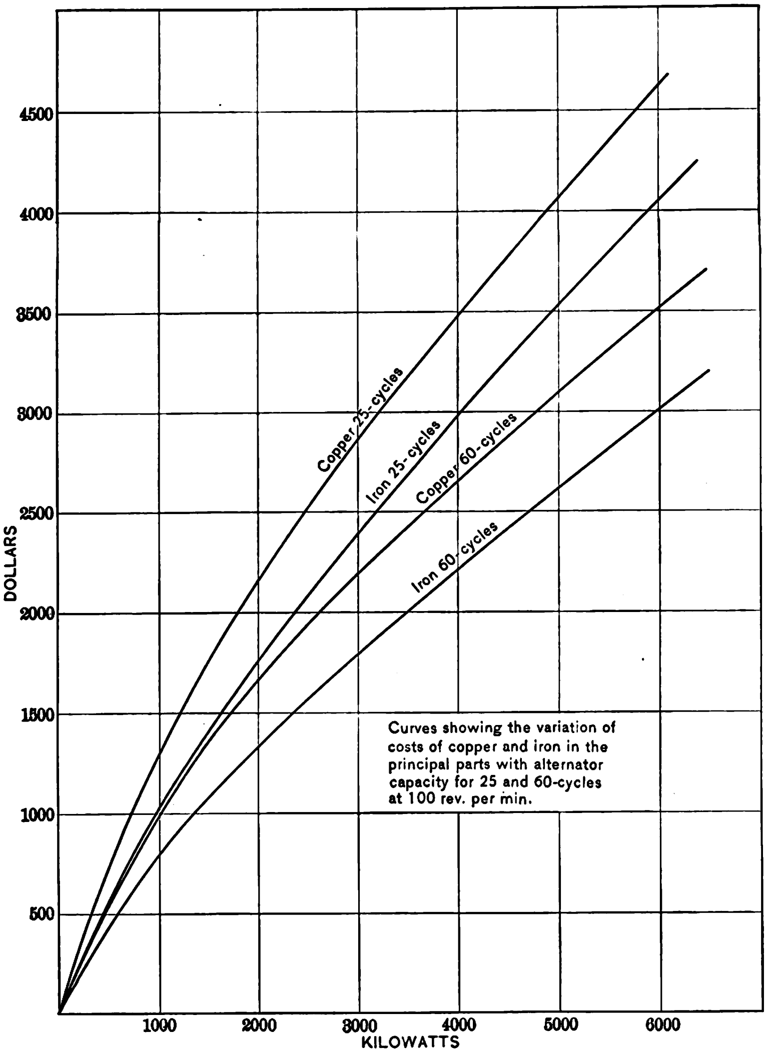


Fig. 7

Due to the fact that bases, bearings, and shafts have been included in the total costs of machines operating at 300 rev. per min., and have been omitted for the 100 rev. per min.

machines, the 25-cycle equipment at 300 rev. per min. is more expensive than the 60-cycle at 100 rev. per min.; whereas the reverse is true when only the material in the principal parts is considered.

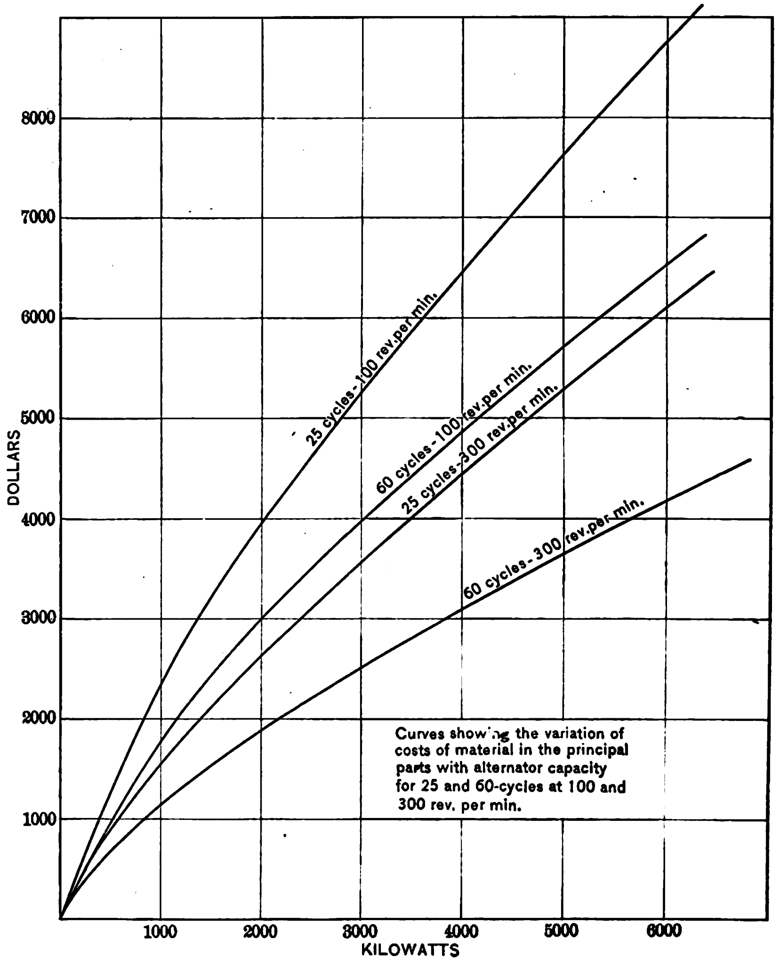
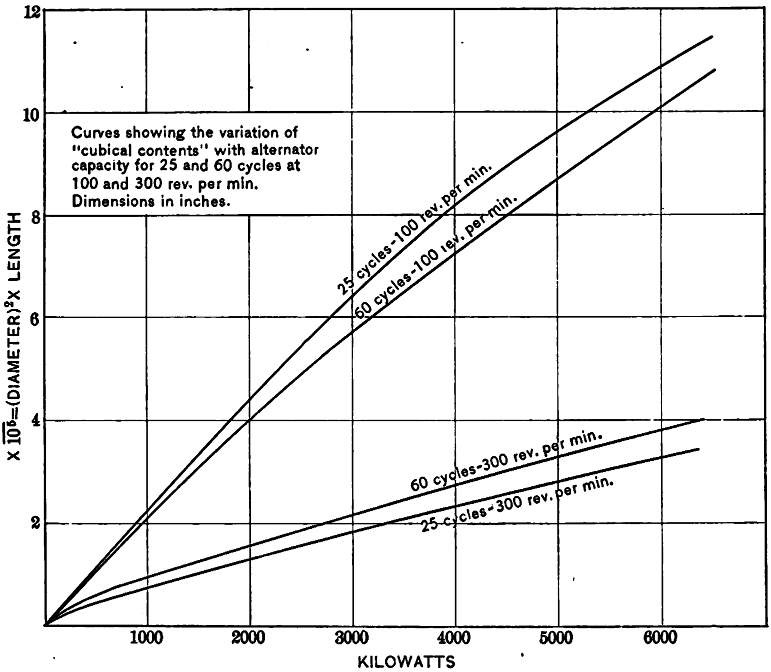


Fig. 8

It will be seen that the 25-cycle machine is about 42 per cent more expensive at 300 rev. per min., and 30 per cent more costly at 100 rev. per min., than the 60-cycle machine for the same output, voltage, and phase. This difference will be slightly greater in the high-speed machines for small outputs in which it is not possible with our present construction, when operating at low power-factors, to keep the temperature rise of the fields of the 25-cycle machines within reasonable limits, when that value of flux is employed to obtain the cheapest machine, unless a prohibitively large diameter be used. Moreover, the greater axial length and lower peripheral speed of the 25-cycle machines will cause the temperature rise of their stator coils to be greater for the same watts loss per square inch of radiating surface, than in the equivalent 60-cycle machines, for which due allowances were made in estimating the curves. On the other hand, somewhat more costly conductors must be used in the 60-cycle machines for large outputs, due to the greater eddy-current loss in them. The use of a larger number of stator slots causes the dies and windings to be somewhat more expensive in the slow-speed 60-cycle machine than in the 25-cycle machine for the same rating. This, combined with the fact that there are a greater number of poles in the slow-speed 60-cycle machines, will probably cause their cost to



Curves showing the variation of "cubical contents" with alternator capacity for 25 and 60 cycles at 100 and 300 rev. per min. Dimensions in inches.

FIG. 9

be somewhat more than was allowed for in estimating the curves in Fig. 10, thus causing the difference in cost between 25-cycle and 60-cycle machines at 100 rev. per min. to be slightly less than the curves indicate.

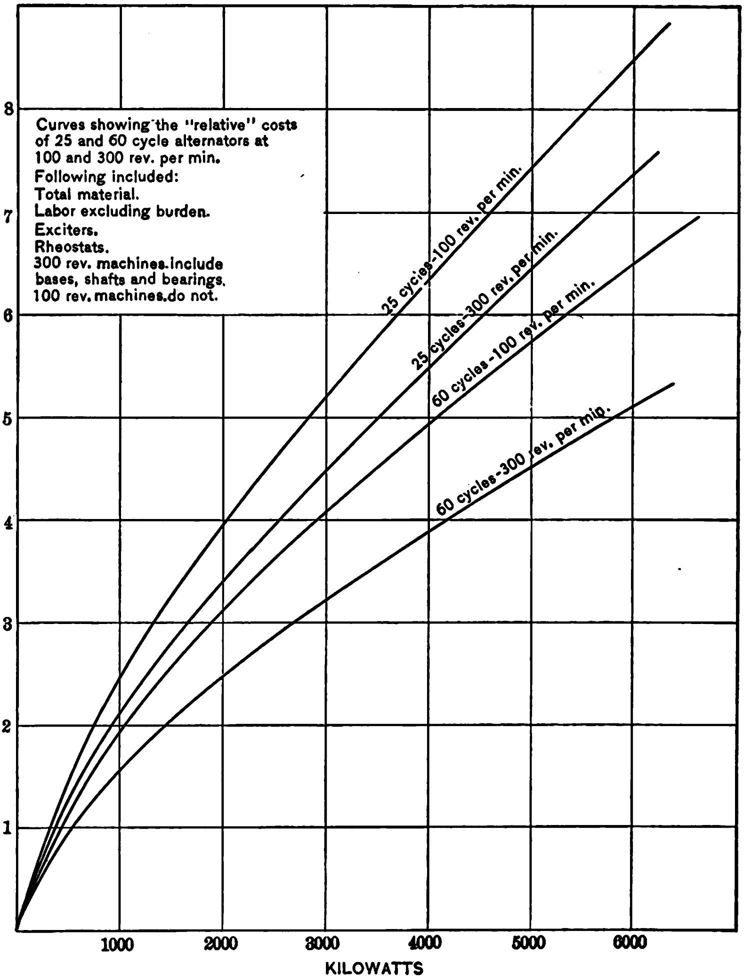


FIG. 10

The great weights of the poles and field copper of the 25-cycle alternators makes the cost of the rotors of 25-cycle machines guaranteed to stand a large overspeed, considerably greater than for the 60-cycle machines for the same rating. The great length of the end-connections of the stator coils for 25-cycle alternators for large outputs at high speeds makes it essential to support them. This is unnecessary in most 60-cycle alternators (excluding turbine-generators), inasmuch as the end-connections are shorter and the reactance of the stator is higher, both of which will tend to prevent the rupture of the end-connections due to the great rush of current at the first instant, when the alternator is short-circuited. We thus see that the difference between the costs of the 25-cycle and 60-cycle machines at 300 rev. per min. will probably be slightly more than would appear from an inspection of Fig. 10.

The writer wishes to thank Mr. A. N. Brown for assistance in determining the costs of exciters and finding the relation which the labor bears to the material.

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THE HEATING OF INDUCTION MOTORS

BY A. MILLER GRAY

The object of this paper is to show the limitations imposed on the designer of induction motors by the heating of the machine, and also to show how this heating may be predetermined.

The highest temperature at which an electrical machine should ever be operated, is that at which the insulation begins to deteriorate due to the action of heat. With the present practice in insulating, the temperature of the stator coils of an induction motor should not exceed 85° cent. for any length of time. The same limitation holds for the rotor coils of a wound rotor machine. The temperature of the rotor of a squirrel-cage motor is only limited by the fact that a hot rotor causes a hot stator, because the hot air from the rotor has usually to pass through the stator coils before it gets out of the machine.

Heating conditions at starting. The squirrel-cage induction motor, with full applied voltage at the terminals, gives a starting torque of about 1.8 times full-load torque, with about 6 times full-load current, or, for full-load torque, the current in the motor is 4.5 times full-load current.

The operation of such a machine can best be shown by the circle diagram Fig. 1.

a b—represents the loss in the rotor end connectors, with the rotor in the locked position.

b c—that in the rotor bars.

c d—the rotor stray loss, which cannot be calculated.

d e—the stator stray loss, which cannot be calculated.

e f—the stator I^2R loss.

f g—the windage, friction, and core loss, which are assumed constant.

At starting, the losses in a squirrel-cage motor are very large, while the speed, on which the power of the motor to get rid of heat depends to a great extent, is low, therefore the heat generated in the various parts of the machine at starting, must be absorbed by these parts.

To determine the temperature rise of the rotor bars at starting. The resistance of copper at the usual working temperature of a motor is 1 ohm per circular mil per inch, therefore the loss in the rotor bars = I^2R watts.

$$= \frac{I^2 \lambda n}{\textcircled{M}} \text{ watts.}$$

Where I = the effective rotor current in each bar.
λ = the length of the rotor bar in inches.
n = the number of bars.
$\textcircled{M}$ = the area of each bar in circular mils.

The heat absorbed by the rotor bars =
$n\times\lambda\times\square''\times.32\times.092\times\theta$ calories per sec.

Where $\square''$ = the area of each bar in sq. in.
0.32 = the weight of 1 cu. inch of copper.
0.092 = the specific heat of copper.
θ = the temperature rise per sec. in degrees cent.

$$\frac{I^2 \lambda n}{\textcircled{M}} \text{ watts} = \frac{I^2 \lambda n}{\square''\times 1.27\times 10^6}\times\frac{1}{746}\times\frac{550}{1}\times\frac{1}{774}\times\frac{5}{9}$$

calories per sec.

$$= \frac{I^2 \lambda n}{\square''\times 1.27\times 10^6}\times 0.00053 \text{ calories per sec.}$$

$$= n\,\lambda\,\square''\times 0.32\times 0.092\times\theta$$

therefore θ = temp. rise per sec. in deg. cent. $= 1.4\times 10^{-8}\left(\frac{I}{\square''}\right)^2$

$$= 2.28\times 10^4\left(\frac{I}{\textcircled{M}}\right)^2 \qquad (1)$$

The value $\frac{\textcircled{M}}{I}$ is seldom less than 400 in the rotor bar at full load, and therefore for full-load torque at starting the $\frac{\textcircled{M}}{I}$ =

the circular mils per ampere $= \frac{400}{4.5}$ approx. $= 89$; and the temperature rise per second from equation 1 = 2.9 degrees cent.

To determine the size of the rotor end connectors. Let P_c be the loss in each ring in watts at starting, required to give the necessary starting torque.

$$P_c \text{ watts} = P_c \times 0.00053 \text{ calories per sec.}$$
$$= \omega \times S \times \theta$$

Where ω = the weight of each ring in lb.
S = the specific heat of the rings assumed = 0.092.

therefore,

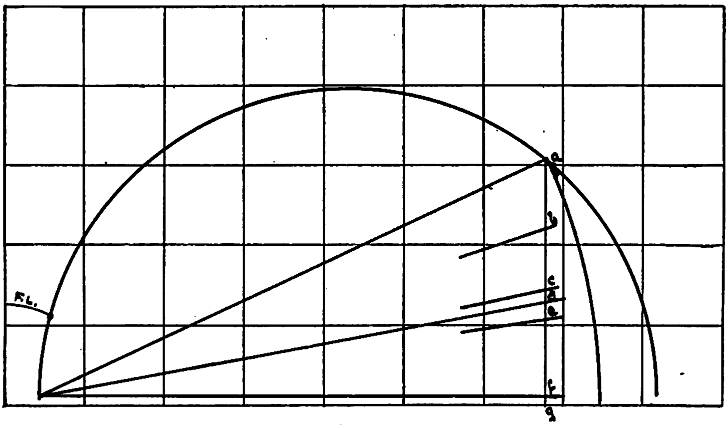

FIG-1

the temperature rise per sec. per watt per lb.

$$= \frac{0.00053}{0.092} = \frac{1}{173} \text{ degrees cent.} \qquad (2)$$

or for 1 synchronous h.p. per lb. the temp. rise = 4.3° cent. per sec. The proper weight of ring to be used in any particular case depends on the starting torque required, and the time needed to bring the motor up to speed. For motors up to about 50 h.p., where the starting duty is not severe, 1.5 synchronous h.p. per lb. will give satisfactory results.

To determine the temperature rise of the stator windings at starting. This may be found in a similar way to that used for the determination of the temperature rise of the rotor copper; namely:

$$\theta = \text{temp. rise per sec. in degrees cent.} = 2.28 \times \left(\frac{I}{\textcircled{M}}\right)^2 \times 10^4$$

This temperature rise cannot be measured by thermometer, because the rate of increase of temperature is so rapid that the heat does not get through the insulation. In making static torque tests on induction motors, the stator coils may often be smoking and yet the coils not feel exceptionally warm to touch.

Test results. The following starting tests are of interest in connection with the previous discussion. A squirrel-cage induction motor was supplied with rings of extra high resistance and was connected up for experiment to a rotating mass having a large moment of inertia and a small friction loss. Such a rotating mass is found in the rotating field of a turbine alternator.

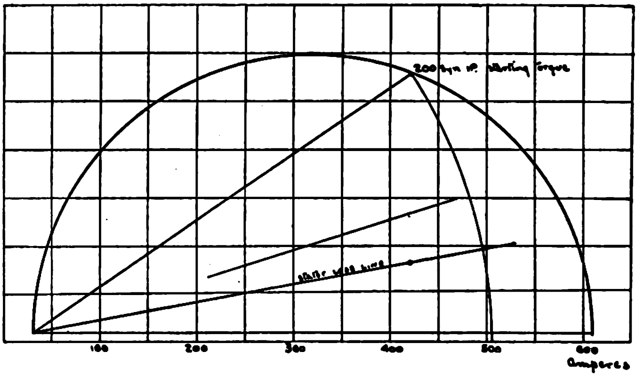

FIG. 2

The operation of the machine in question is shown by the circle diagram Fig. 2.

The moment of inertia of the rotating mass = 36,000 lb.-ft.^{2}

The tests were made on half voltage, under which conditions the

$$\frac{\textcircled{M}}{I} \text{ stator} = 249$$

$$\frac{\textcircled{M}}{I} \text{ rotor} = 164$$

Weight of each ring = 23 lb.

P_c = watts lost in each ring = 13750 watts = 18.5 synchronous h.p.

H.p. per lb. of ring = 0.8

The calculated temperature rises per second from equations 1 and 2 are:

stator coils—0.37 °cent.

rotor bars—0.85 °cent.

rotor end connectors—3.4 °cent.

The speed-time and current-time curves of the machine are shown in Fig. 3. About 60 seconds after starting, smoke began to come from the stator windings, and the stator continued to smoke until the speed rose to 50 per cent of full-load speed, at which point the stator current had fallen to 83 per cent of the starting current, and the ventilation was more than able to take care of all the heat generated.

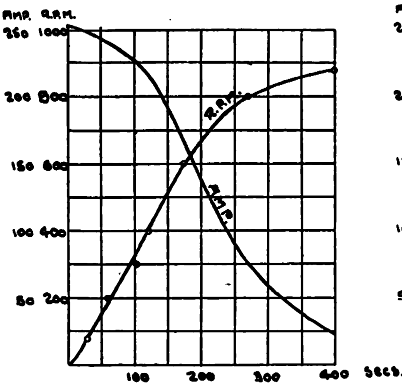

FIG-3

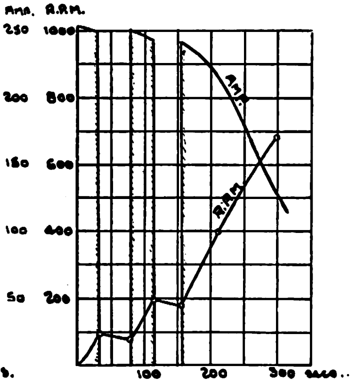

FIG-4

At 253 amperes starting current, the circular mils per ampere is 249 and the calculated temperature rise 22° cent. in 60 seconds, which is not sufficient to cause the machine to heat up as it did. To test this point a direct current of 300 amperes was sent through all three phases of the stator; the rotor was stationary. Under these conditions the temperature rose from 16° cent. to 103° cent. by thermometer in six minutes, at which temperature smoke began to appear. The cause of the excessive heating when the motor was started up must therefore be due to the high temperature of the rotor end connectors. The construction of this machine is similar to that shown in Fig. 5. The rotor end connectors H are close to the stator windings E so that, if the former are very hot, the latter will be scorched on the outside. In the actual test the rings began to oxidize in about a minute after starting, and they were highly discolored before the motor was up to speed.

The total rotor loss at starting = 37,000 watts.
= 50 syn. h.p.
The weight of two end connectors = 46 lb.
of rotor bars = 66 lb.
of rotor laminations = 200 lb.
Total rotor 312 lb.

If the heat generated in the rotor bars and end connectors had time to diffuse all through the rotor, the rotor temperature rise would be from equation (2)

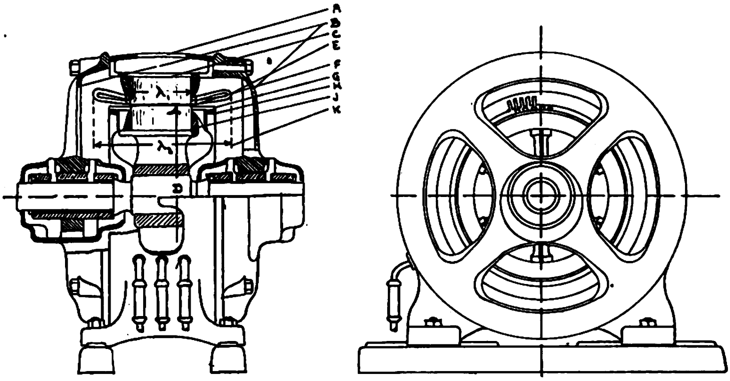

Fig-5

$$\frac{50}{312} \times 4.3 = 0.61° \text{ cent. per sec.}$$

An attempt to approximate to this condition was made by bringing the machine up to speed in steps as shown in Fig. 4. In this case the rings remained untarnished and the temperature rise on the windings was only 51° cent. by thermometer. The machine showed no signs of high temperatures.

Heating of induction motors under running conditions. Before discussing any particular type of construction or system of ventilation, attention must be drawn to the fact that in an induction-motor stator, built up of laminations which are insulated from each other by paper or by varnish, the thermal conductivity of the core is not the same in all directions; for example,* in the case of a core built with alternate layers of iron 0.020 in. thick and of paper 0.002 in. thick, the conductivity was as follows:

Along the laminations—0.1365 gram = calories per cm. per sec. per degree cent.

Across the laminations—0.0013 to 0.0025 gram = calories per cm. per sec. per degree cent.

The latter quantity varied with the structure of the paper and the kind of scale on the iron.

It was also found, by blowing air across the radiating surface of the core, that the watts per sq. cm. radiating surface per degree cent. rise was equal to $0.0038\ (1+0.25\ v.)$ where $v =$ the air velocity in metres per sec.

The following discussion of induction motor heating is based on the type of machine shown in Fig. 5.

The system of ventilation of this machine is as follows: air is drawn in at K, passes between the rotor end head J and the rotor end connector H and then through between the rotor bars G.

Leaving the rotor, the moving air strikes the stator windings F and some of the air passes through the windings; the remainder of the air moves along the coils to E, then, as it still has a considerable radial velocity, some of the air strikes the inside of the housing at B, and is deflected back over the outer surface of the stator coils and then over the laminations C, before it leaves the machine at A.

An important feature about the construction of this machine is that the moving air is not passed out of the machine after cooling the stator coils, but passes over the back of the stator laminations with a fairly high velocity, in this way getting the effect, which the experiments on conduction just mentioned would indicate as desirable to obtain.

Table I gives a number of heat runs on a motor of this type and of the following dimensions:—

$D =$ dia. of rotor $= 33$ in.
$\lambda_1 =$ length of core $= 4.5$ in.
$\lambda_2 =$ length over coils $= 15.125$ in.

---

* *London Electrician*, March 7, 1907.

TABLE I.

Test No.	Stator loss in kw.			Stator temp. rise in °cent.				$\frac{I^2R - \text{core loss}}{\text{core loss}}$	$\frac{\text{core loss} - I^2R}{I^2R}$	$\frac{\text{temp. rise copper}}{I^2R}$	$\frac{\text{temp. rise iron}}{\text{core loss}}$
				Machine running		After shut down					
	I^2R 1	Core loss 2	Total 3	Copper 4	Iron 5	Copper 6	Iron 7	8	9	10	11
1	2.09	1.6	3.69	21	22	21½	22	0.307	−0.235	10.3	13.8
2	2.8	1.6	4.4	24½	23	27	26	0.75	−0.428	9.65	16
3	3.08	1.6	4.68	26	25	27.7	26.5	0.925	−0.48	9.0	16.6
4	2.9	3.7	6.6	26	29	30	31	−0.216	0.275	10.4	8.4
5	3.64	3.7	7.34	35½	35½	36½	36½	−0.016	0.0165	10	9.9
6	2.2	4.2	6.4	21	25½	22	26	−0.475	0.91	10	6.2
7	3.6	4.2	7.8	33	34½	34	35½	−0.143	0.166	9.5	8.4

$\sim$ = frequency = 60 cycles.
p = number of poles = 10.
synchronous speed in rev. per min. = 720
S = % slip at full load = 4% approx.

Column 1 gives the stator $I^2 R$ in kilowatts.

R is the resistance at the air temperature measured by direct current. The eddy-current loss is negligible, because the core is short, and the conductor in no case is more than 0.5 in. deep.

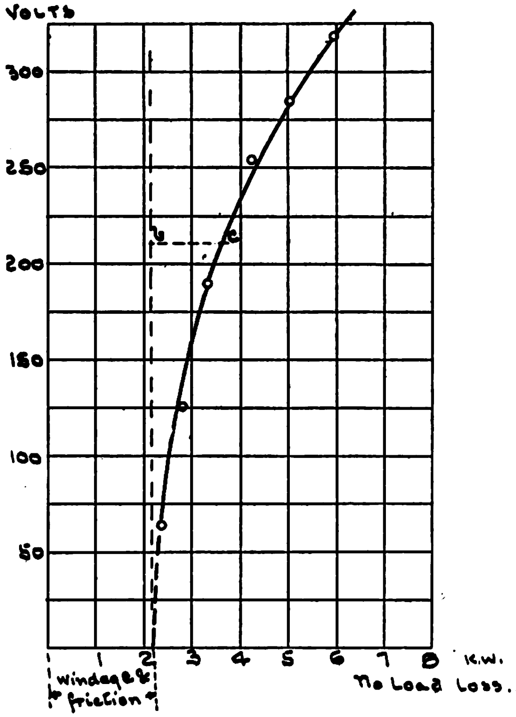

FIG.—6
Induction Motor Core Loss Curve

Column 2 gives the stator core loss in kilowatts. This is taken directly from the saturation curve Fig. 6 in the following way:

The saturation curve in Fig. 6 is taken as low as possible and is then continued as shown by dotted part to the base line. The core loss at 220 volts then = $b\,c$ = 1.6 kw.; at 330 volts = 3.7 kw. and at 360 volts = 4.2 kw.

Columns 4 and 5 give the temperatures of the stator copper and iron while the machine is still running under load.

Columns 6 and 7 give the same temperatures after the machine has been shut down and the heat has come out, to use a shop phrase. The temperature always rises a little after shut-down because, under running conditions, the internal parts of the machine are hotter than the parts on which the thermometers are placed; while after shut-down, the temperature tends to become uniform throughout the stator.

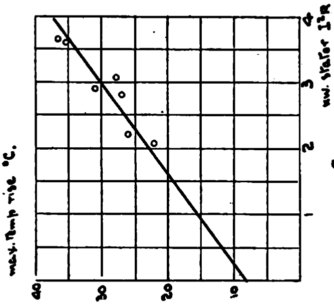

FIG. 8

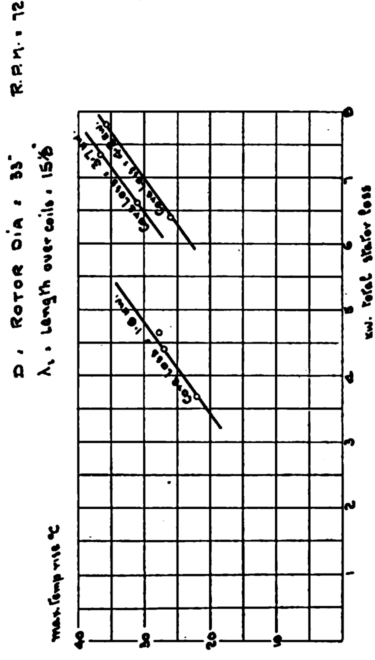

FIG. 7

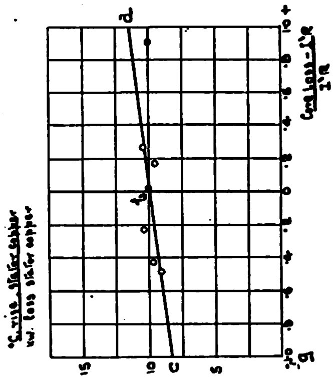

FIG. 10

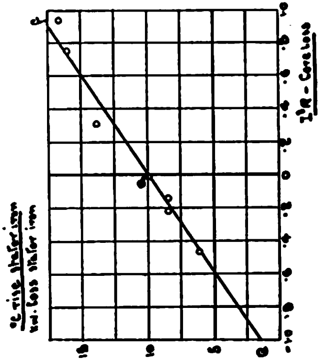

FIG. 9

These temperatures are all measured by thermometer. In the case of the stator coils the thermometer bulb is pushed into the windings and is protected from the direct ventilation of the machine. In the case of the stator iron, the thermometer bulb is laid on the back of the laminations at a point where it is protected from air blowing through the vent ducts. The bulb is then covered with a pad of waste. This pad is in such a position and is of such a size that it will not interfere with the natural ventilation of the machine.

Two important points are to be seen from these tests:

1. Irrespective of the distribution of the stator loss between the copper and the iron, the final temperature of the copper, after shut-down, is approximately equal to the final temperature of the iron, in any one test.

2. The temperature rise is not proportional to the total stator loss. It is more nearly proportional to the $I^2 R$ loss of the stator. This is well shown in curves, Fig. 7 and 8, plotted from the tests of Table I.

The former of these two points shows that there is a transfer of heat from the hotter parts of the machine to the cooler parts, and suggests the following method of plotting heating data. The method is purely an empirical one, but it gives good results.

The temperature rise of the stator iron $= t_2$
" " " " " " copper $= t_1$

The following assumptions are made

$$t_1 = K_1 (I^2 R) + K_2 (\text{core loss} - I^2 R)$$
$$t_2 = K_3 (\text{core loss}) + K_4 (I^2 R - \text{core loss})$$

or

$$\frac{t_1}{I^2 R} = K_1 + K_2 \left(\frac{\text{core loss} - I^2 R}{I^2 R}\right) = \frac{\text{temp. rise copper}}{\text{kw. copper loss}}$$

$$\frac{t_2}{\text{core loss}} = K_3 + K_4 \left(\frac{I^2 R - \text{core loss}}{\text{core loss}}\right) = \frac{\text{temp. rise iron}}{\text{kw. iron loss}}$$

The curve in Fig. 9 gives

$$\frac{t_2}{\text{core loss}} \text{ plotted against } \frac{I^2 R - \text{core loss}}{\text{core loss}}$$

The curve in Fig. 10 gives

$$\frac{t_1}{I^2 R} \text{ plotted against } \frac{\text{core loss} - I^2 R}{I^2 R}$$

from the tests of Table I.

TABLE II.

Stator loss in kw.			$\frac{I^2R - \text{core loss}}{\text{core loss}}$	$\frac{\text{core loss} - I^2R}{I^2R}$	temp. rise copper $\frac{}{I^2R}$ from curve—10	temp. rise iron $\frac{}{\text{core loss}}$ from curve—9	Calculated temperature rise	
I^2R	Core loss	Total					Copper	Iron
1	6	7	-0.83	5.0	19° C.	3° C.	19	18
2	5	7	-0.6	1.5	12.7	5	25	25
3	4	7	-0.25	0.33	10.6	8	32	32
4	3	7	0.33	-0.25	9.6	13	38	39
5	2	7	1.5	-0.6	9.0	23	45	46
6	1	7	5.0	-0.83	8.6	53	52	53

TABLE III.

Test No.	Amp. stator	Kw. stator loss		° cent. temp. rise					$\frac{I^2R - \text{core loss}}{\text{core loss}}$	$\frac{\text{core loss} - I^2R}{I^2R}$	$\frac{\text{temp. rise copper}}{I^2R}$	$\frac{\text{temp. rise iron}}{\text{core loss}}$
				Stator		Rotor						
		I^2R	Core loss	Copper	Iron	Cond.	Ring	Iron (inside)				
1	180	2.9	4.1	28½	30	21	21	19	-0.292	0.414	9.8	7.4
2	227	4.6	4.1	41	43	31	33	26	0.122	-0.108	9	10.4
3	180	2.9	4.1	39	41	34	35	33	-0.292	0.414	13.4	10
4	227	4.6	4.1	59	58	50	50	46	0.122	-0.108	12.8	14.2

The effect of the distribution of loss on the temperature rise is shown in a very striking manner by the following figures taken from curves 9 and 10.

Analysis of the temperature loss diagram. It has been pointed out in discussing the tests of Table I, that the final temperature of the stator copper after shutdown is approximately equal to the final temperature of the stator iron in any one test. Therefore, *o a*, Fig. 9, the temperature rise of the iron per kw. iron loss at the point where core loss = $I^2 R$ loss, must equal *o b*, Fig. 10, the temperature rise of the copper per kw. $I^2 R$ loss, at the same point.

If then *o b* can be predetermined, and also the slope of the copper line *c d*, Fig. 10, the iron line *e f*, Fig. 9, can be drawn in, because the copper and iron temperatures are about equal at any load.

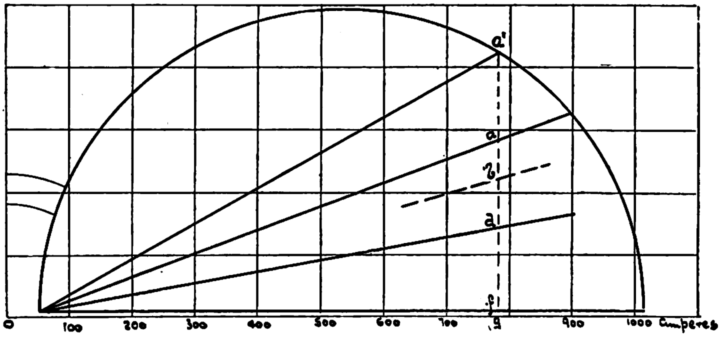

FIG - 11

The reason why it is desirable to predetermine *o b* rather than *o a* is that, as has been shown in Figs. 7 and 8, the copper loss is a more important factor in determining the temperature rise than the iron loss is.

Effect of a high resistance rotor on the stator temperatures. Table 3 gives four heat runs on a motor of construction similar to Fig. 5 and of the following dimensions:

D = 33 in.

$\lambda_1 = 7\frac{1}{4}$ in. The machine has a 1.5-in. vent-duct in the center of the stator and rotor cores.

λ_2 = 17.25 in.
$\sim$ = 60 cycles.
p = 12 poles.
synchronous rev. per min. = 600.

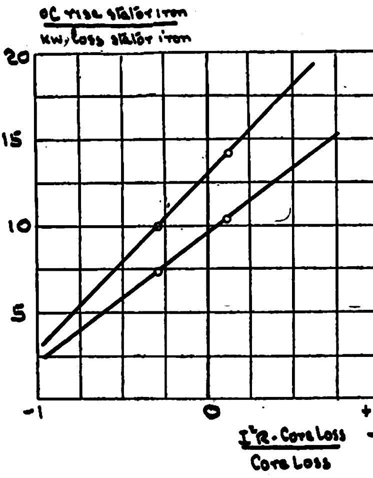

FIG-12

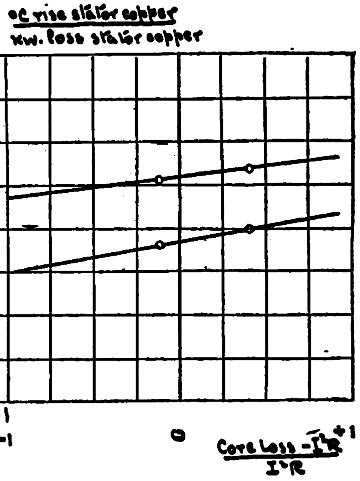

FIG-13

EFFECT of HIGH ROTOR RESISTANCE

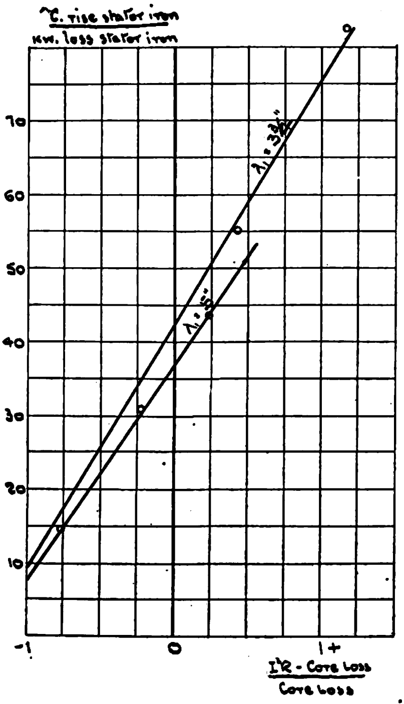

FIG-14

Machine - 14½" dia.

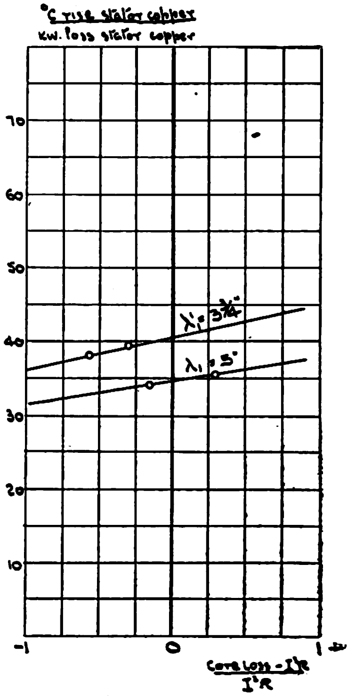

FIG-15

This machine was tested with two different sets of rotor end connectors, all other things being unchanged. The effect of the change in the end connectors may be seen from Fig. 11, where

$a\,b$ = the rotor end connector loss at the lock point in tests 1 and 2, table 3.

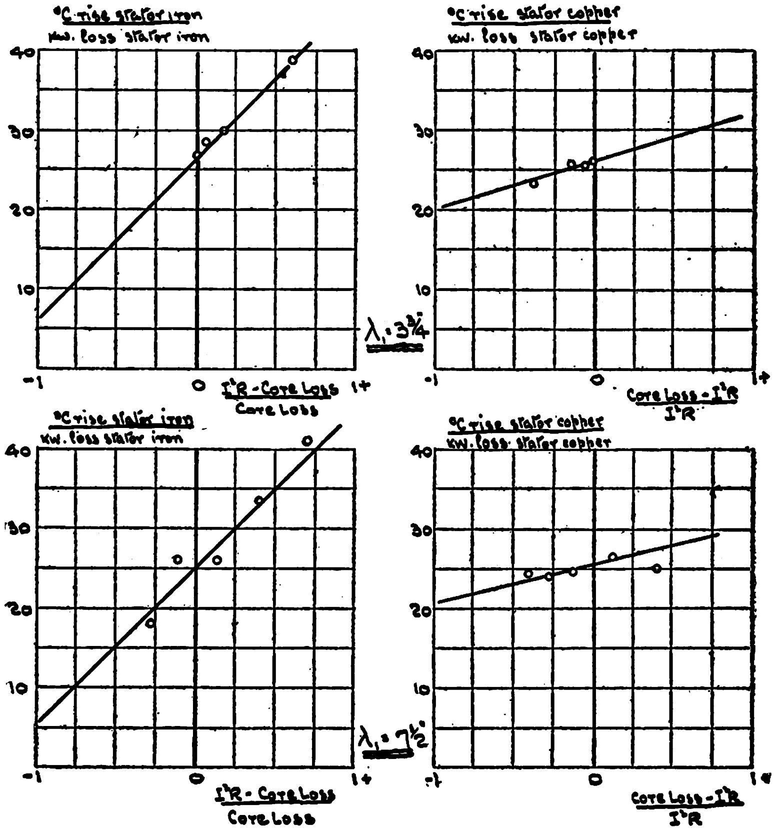

FIG-16 Machine-20' dia. FIG-17

$a^1\,b$ = the rotor end connector loss at the lock point in tests 3 and 4, table 3.

$b\,d$ = the rotor bar loss, which was unchanged.

These results are plotted in curves, Fig. 12 and 13, and show that with an increased rotor loss of 100 per cent there is an increase in temperature rise of 40 per cent.

TABLE IV.

D''	λ_1''	λ_2''	Kw. stator loss		° cent. Stator temp. rise		I^2R – core loss	core loss – I^2R	temp. rise copper ° cent.	temp. rise iron
			I^2R	Core loss	Copper	Iron	core loss	I^2R	I^2R	core loss
14½	3¼	11⅝	0.72	0.5	28½	27½	0.44	–0.305	39½	54
"	"	"	1.15	0.5	44	41½	1.3	–0.56	38	83
"	5	12⅝	0.7	0.9	25	28	–0.22	0.29	35½	31
"	"	"	0.96	3.2	40	45½	–0.67	2.34	42	14.2
"	"	"	1.12	0.9	38	39	0.245	–0.196	34	43.5
20	3⅘	11⅞	0.69	0.67	18	18	0.005	–0.003	26	26.8
"	"	"	0.71	0.67	19	18	0.06	–0.056	25.3	28.4
"	"	"	1.08	0.67	26	26	0.61	–0.38	23.2	38.8
"	"	"	0.93	0.8	24	24	0.175	–0.15	25.7	30
20	7½	16½	1.37	1.2	34	31½	0.142	–0.124	24.7	26
"	"	"	2.04	1.2	50	49½	0.7	–0.41	24.5	41
"	"	"	0.93	1.3	23½	23½	–0.285	0.4	25	18
"	"	"	1.6	1.15	38½	38½	0.39	–0.28	24	33.5
"	"	"	1.6	1.8	43	47	–0.11	0.125	26.5	26

Effect of changing the length of machine. The tests in Table IV, were made on four machines built like Fig. 5; the dimensions of these machines are shown under columns D, λ_1 and λ_2.

The results of these tests are plotted in curves Fig. 14 and 15 for the machines 14.5 in. diameter, and Fig. 16 and 17 for the machines 20 in. diameter. These latter curves are plotted separately for the two lengths of machine because they lie so nearly on the top of each other.

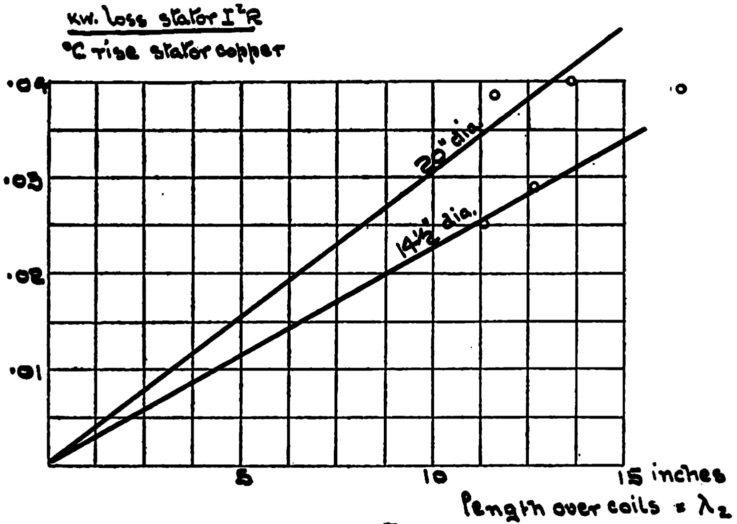

FIG.-18

From Figs. 15 and 17, at the point where core loss = stator I^2R, the value of

deg. cent. rise stator copper / kw. loss stator copper	D	λ_1	λ_2	kw. loss stator copper / deg. cent. rise stator copper
40.5	14½	3¾	11⅜	0.025
34.5	14½	5	12⅝	0.029
26	20	3¾	11⅞	0.0385
25 see table 7	20	5½	13⅝	0.04
25.5	20	7½	16½	0.0393

These results are plotted in the curve shown in Fig. 18.

It will be noted that in the case of the 14.5 in. diameter machine

that $\dfrac{\text{kw. loss stator copper}}{\text{deg. cent. rise stator copper}}$ is directly proportional to λ_2.

In the case of the 20-in. machine, however, the ratio is nearly constant, that is, there is nothing gained, so far as heating is concerned, by lengthening the machine.

There is a reason for this, however, which adds interest to the results. In the 14.5-in. machine the same bearings and fans are used on both lengths. In the 20-in. machine, on the other hand, as the machine is lengthened, the size of the bearings is increased, and thereby the air inlet is diminished in size. The fans have to be made smaller in order to clear the larger bearing housings, and the hub of the spider has to be increased in order to take care of the larger shaft. It is therefore reasonable to assume that for equally good ventilation

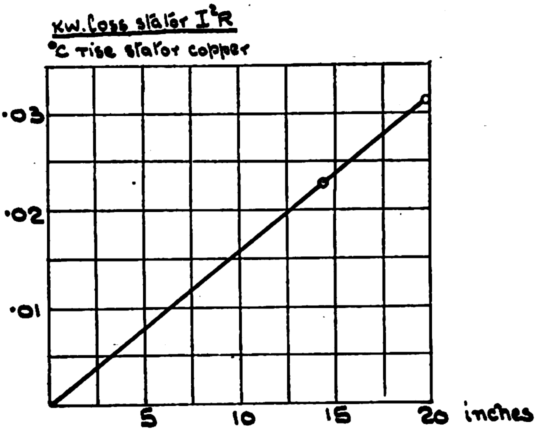

FIG.-19

$$\frac{\text{kw. loss stator copper}}{\text{deg. cent. rise stator copper}}$$

is directly proportional to λ_2.

Effect of changing the diameter of machine. From the curve in Fig. 18, assuming a constant length over the coils = λ_2 = 10 in.

$$\frac{\text{kw. loss stator copper}}{\text{deg. cent. rise stator copper}} = 0.0225 \text{ where } D = 14.5 \text{ in.}$$

$$0.031 \quad \text{"} \quad D = 20 \text{ in.}$$

These two figures are plotted in curve Fig. 19 from which it will be seen that:

$$\frac{\text{kw. loss stator copper}}{\text{deg. cent. rise stator copper}} \text{ is directly proportional to } D.$$

Effect of the diameter of bearing. It has already been suggested in the case of the 20-in. diameter machine that the size of the bushing may affect the heating to some extent.

The following tests bear this out.

A machine with dia. $D = 17$ in., $\lambda_1 = 13.5$ in. with four 0.5-in. vent ducts, $\sim\ = 25$ cycles, $p = 4$, was tested first with a set of bearings 3 in. by 9 in. and again with a set of bearings 4 in. by 10 in. the fans and spider hub being unaltered, with the following results:

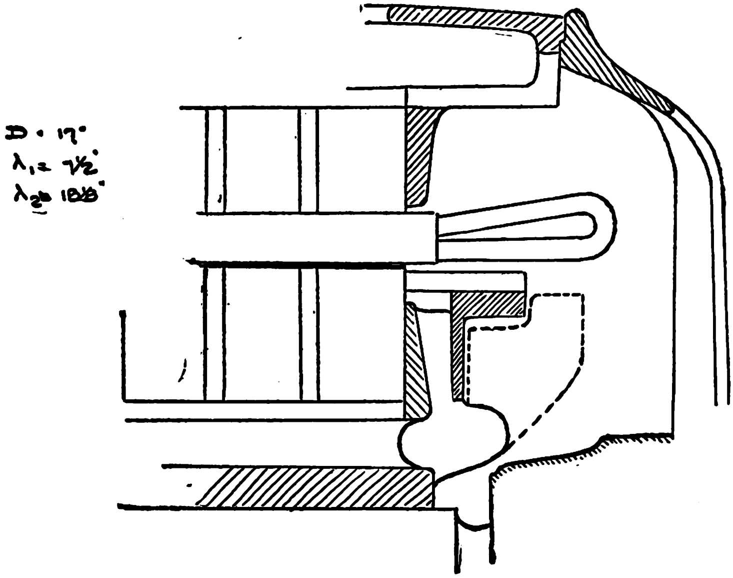

FIG. – 20

Bearings	Kilowatt stator loss		Temp. rise in deg. cent.	
	Copper	Iron	Copper	Iron
3 by 9	1.8	2.3	43	39
3 " 9	2.78	2.3	58	53
4 " 10	1.8	2.3	49	45.5
4 " 10	2.78	2.3	65.5	57

TABLE V.

~	Syn. r.p.m.	Kw. stator loss		° Cent. Stator temp. rise		$\frac{I^2R - \text{core loss}}{\text{core loss}}$	$\frac{\text{core loss} - I^2R}{I^2R}$	$\frac{\text{temp. rise copper ° cent.}}{I^2R}$	$\frac{\text{temp. rise iron ° cent.}}{\text{core loss}}$
		I^2R	Core loss	Copper	Iron				
25	750	1.06	1.4	40	36½	−0.242	0.32	37.5	26
"	"	0.975	1.15	37	32½	−0.152	0.18	38	28.5
"	"	0.815	1.4	33½	32	−0.417	0.72	41	23
40	1200	0.91	1.1	27	25	−0.173	0.208	29.5	22.7
60	1800	0.97	2.8	25	25	−0.65	1.88	25.8	8.9
"	"	1.38	2.8	32	32	−0.505	1.02	23	11.4

TABLE VI.

~	Syn. r.p.m.	Kw. stator loss		° cent. Stator temp. rise		$\frac{I^2R - \text{core loss}}{\text{core loss}}$	$\frac{\text{core loss} - I^2R}{I^2R}$	$\frac{\text{temp. rise copper ° cent.}}{I^2R}$	$\frac{\text{temp. rise iron ° cent.}}{\text{core loss}}$
		I^2R	Core loss	Copper	Iron				
25	750	1.24	1.05	25	24	0.18	−0.153	20.2	22.8
"	"	1.95	1.05	39	34	0.86	−0.46	20	32.5
"	"	0.18	2.1	10½	16	−0.91	10.7	58	7.6

The increase in temperature rise, due to the use of the larger bearings and shaft, is 14 per cent.

Effect of peripheral speed on heating. A machine of the dimensions shown in Fig. 20 was run under the following conditions shown in Table V.

The above tests were made without the rotor fans which are shown dotted. These results are plotted in curves Fig. 21 and Fig. 22.

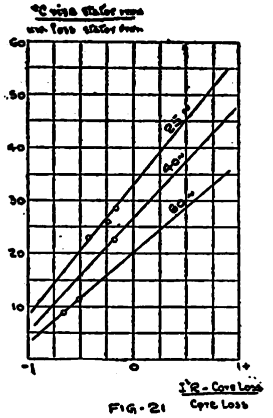

FIG. 21

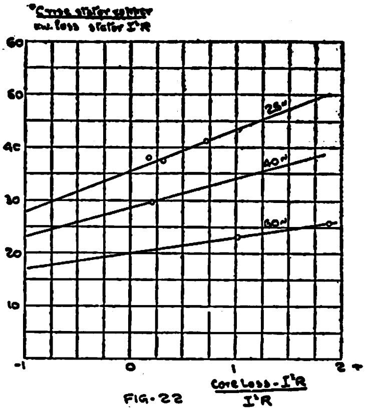

FIG. 22

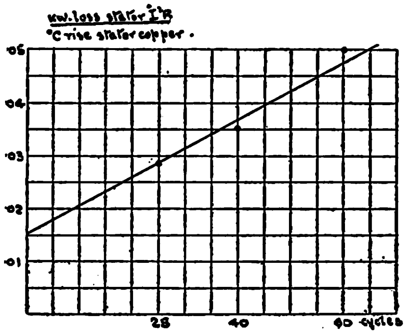

FIG. 23

TESTS on an INDUCTION MOTOR

RUN at DIFFERENT FREQUENCIES

From curve Fig. 22 at the point where $I^2 R$ = core loss, we have

$$\frac{\text{deg. cent. rise stator copper}}{\text{kw. loss stator } I^2 R} = \begin{array}{lll} 20 & \text{for } 60 & \text{cycles.} \\ 28.5 & \text{“} \quad 40 & \text{“} \\ 35.5 & \text{“} \quad 25 & \text{“} \end{array}$$

or the reciprocal, viz.:

$$\frac{\text{kw. loss stator } I^2 R}{\text{deg. cent. rise stator copper}} = \begin{array}{lll} 0.05 & \text{for } 60 & \text{cycles.} \\ 0.035 & \text{“} \quad 40 & \text{“} \\ 0.028 & \text{“} \quad 25 & \text{“} \end{array}$$

These latter results are plotted in Fig. 23, which curve shows that the heat is got rid of by radiation and by convection; the former is independent of the speed of the machine; the latter is directly proportional to speed.

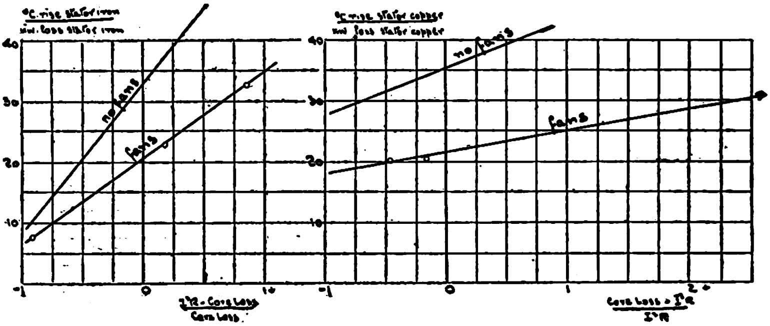

FIG-24

To find the constant of radiation.

$$\text{At standstill } \frac{\text{kw. loss stator } I^2 R}{\text{deg. cent. rise stator copper}} = 0.015.$$

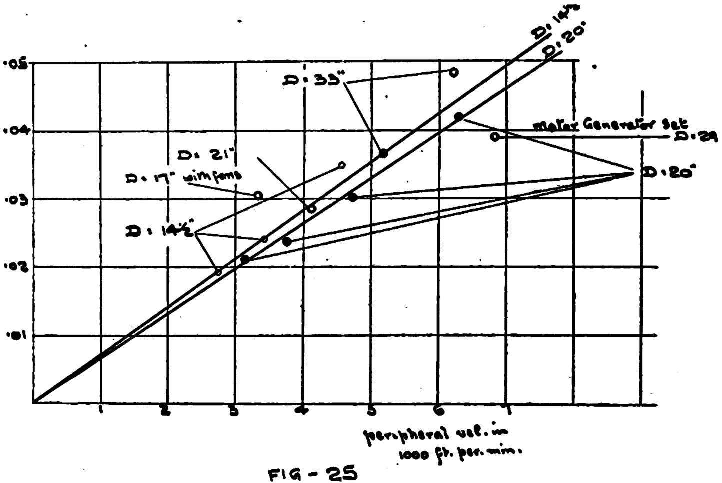

FIG - 25

The radiating surface of the machine is taken as

$$\pi \times \text{diameter} \times \lambda_2 = \pi \times 17 \times 18\tfrac{1}{8} = 970 \text{ sq. in.}$$

therefore,

deg. cent. rise per watt $I^2 R$ per sq. in. radiating surface

$$= \frac{1 \times 970}{0.015 \times 1000} = 65 \text{ deg. cent.}$$

This value has been checked on other diameters and lengths of machines.

Effect of fans on heating. The same machine was supplied with sheet metal fans as shown by the dotted lines, Fig. 20, with the results as shown in Table VI.

These results are plotted in curves in Fig. 24.

General summary of results. Table 7 gives a summary of the tests already quoted. The table is self-explanatory, and the results are plotted in the curve in Fig. 25.

Expressing the results in the form of an equation, the temperature rise of an induction motor similar to Fig. 5, at the point where the stator $I^2 R$ loss = stator core loss, is given by:

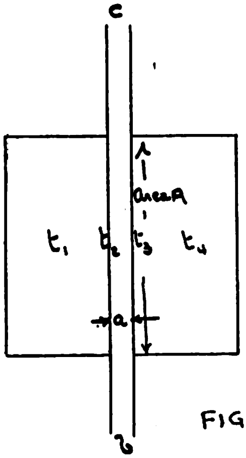

FIG-26

Watts $I^2 R$ for 1 deg. cent. rise

$$= \frac{1000}{N} = \frac{1000}{M} + \frac{1000}{Q}$$

$$= \frac{\pi\ D\ \lambda_2}{65} + 0.0065 \times V \times \pi\ D\ \lambda_2$$

$$= \underline{\pi D \lambda_2 (0.015 + 0.0065 V)}$$

where V = peripheral velocity in 1000 ft. per min.

This equation determines *o b*, Fig. 10, and *o a*, Fig. 9.

TABLE VII

Poles	~	Syn. rev. per min.	D	λ_1	λ_2	$\pi D \lambda_2$	Radiation from motor at rest Assume 65° cent. rise per watt $I^2 R$ per sq. in. $M = $ °cent. rise per kw. $I^2 R$ radiated $= \frac{1000 \times 65}{\pi D \lambda_2}$	 $\frac{1}{M}$ Kw. $I^2 R$ radiated per 1° cent. rise	Heating under load conditions N °cent. rise per kw. $I^2 R$ loss $= o\,b$ Fig. 10	 $\frac{1}{N}$ Kw. $I^2 R$ loss per 1° cent. rise	Effect of ventilation $\frac{1}{Q} = \frac{1}{N} - \frac{1}{M}$ Kw. $I^2 R$ loss taken care of by ventilation per. 1° cent. rise	 $\frac{1}{Q} \times \frac{1000}{\pi D \lambda_2}$ Watts $I^2 R$ per sq. in. taken care of by ventilation per 1° cent. rise	Peripheral velocity in ft. per min.	Remarks
6	60	1200	14½	5	12⅝	575	113	0.0088	34.5 fig. 15	0.029	0.0202	0.035	4560	
8	"	900	"	"	11⅝	530	122.5	0.0082	48	0.0209	0.0127	0.024	3420	
10	"	720	"	"	11⅜	517	126	0.0079	56	0.0178	0.0099	0.019	2750	
6	"	1200	20	3¾	13½	850	76.5	0.0131	20.5	0.049	0.0359	0.042	6300	
8	"	900	"	5½	13⅝	860	76	0.0132	25.5	0.0392	0.026	0.0304	4730	
10	"	720	"	6½	14¼	900	72	0.0139	28.5	0.035	0.0211	0.0235	3780	
12	"	600	"	3¾	10⅞	685	95	0.0105	40	0.025	0.0145	0.0211	3150	
10	"	720	33	4½	15⅛	1570	41.5	0.0241	10	0.1	0.0759	0.0485	6220	
12	"	600	"	5½	15½	1610	40.5	0.0246	12	0.083	0.0584	0.0363	5200	
8	"	900	29	7¼	19¼	1750	37	0.027	10.5	0.095	0.068	0.039	6820	2 bearing motor generator set 3½ in. vent ducts
4	25	750	21	9½	23¼	1535	42.5	0.0235	15	0.067	0.0435	0.0284	4130	4½ in. vent ducts.
4	"	"	17	7⅛	18⅛	970	67	0.0149	22.5	0.0445	0.0296	0.0305	3330	Fig. 20 with fans.

It is still necessary to determine the slope of line *c d* for a complete determination of the temperature rise.

In Fig. 10 *g c* is the value of the deg. cent. rise of the stator copper per kw. stator $I^2 R$ at the point where the core loss = 0. This quantity varies from 70 per cent to 90 per cent of *o b*, depending upon the rotor resistance, construction and size of machine; a good guess based on results of similar machines is the easiest way to determine it.

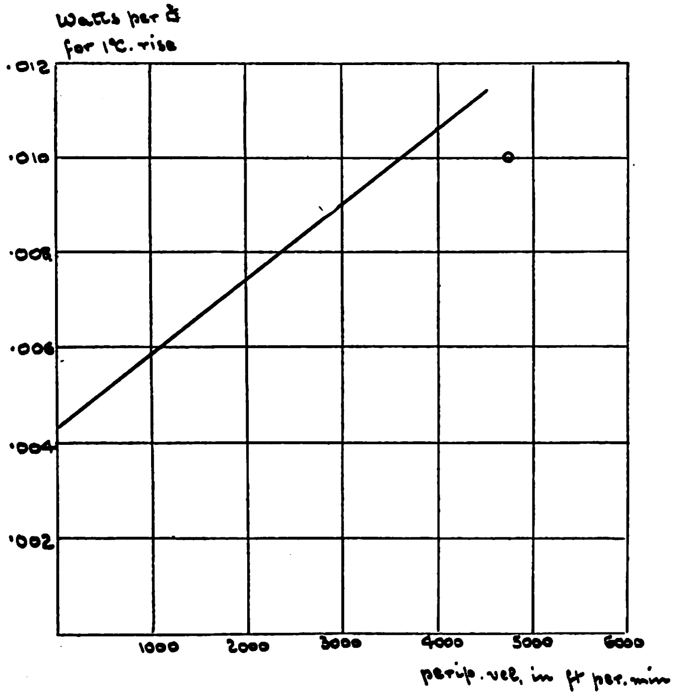

FIG-27

Heating of induction motors totally enclosed. Before discussing this subject the following digression will prove instructive. If *c b*, Fig. 26, be a plate of metal through which heat is passing from, say, steam at one side at a temperature t_1, to water at the other side at a temperature t_4, the flow of heat being steady, then if the plate be not too thick k = the thermal conductivity $= \dfrac{Q\,a}{A\,(t_2 - t_3)}$

Where Q = the quantity of heat passing through the plate per sec.

a = the thickness of the plate.

A = the area of the plate.

t_2 and t_3 = the temperatures of the two sides of the plate. This quantity k was measured by three different experimenters who gave the following values: Clément 0.0057, Péclet 0.178, Angström 1.1,

The-last mentioned result is now recognized as being correct, and the cause of the great discrepancy is of interest in connection with the heating of enclosed machines.

Clément assumed that $t_1 = t_2$ and $t_3 = t_4$. He had steam at the one side at a temperature of 100 deg. cent. and water at the other side at a temperature of 28 deg. cent. He assumed that $t_2 - t_3 = 100 - 28 = 72$ deg. cent., whereas we now know it was only 0.36 deg. cent.

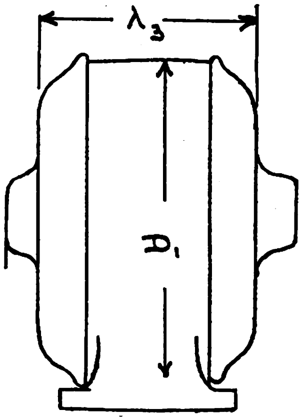

FIG. 28

Péclet improved on Clément's method by putting stirrers in the two chambers, by which means he got 32 times as much heat through the plate; that is, stirring brings the temperature t_1 more nearly equal to t_2, and t_3 more nearly equal to t_4.

It will therefore be seen that ventilation, or stirring up the air, is of as much importance in an enclosed motor as it is in the open type of machine.

In curve, Fig. 27 is plotted the result of a number of tests on a line of well-ventilated direct-current enclosed motors; also one test on a squirrel-cage induction motor, similar to Fig. 5. The radiating surface used to determine the value of watts per sq. in. is that of the total external surface of the frame. It equals

$$\pi D_1 \lambda_3 + \frac{\pi D_1^2}{2}$$

The temperature rise is that of the armature or stator coils.

TABLE VIII

D = 20 in. p = 8 poles. External Radiating Surface = 3260 sq. in.
λ_1 = $5\frac{1}{2}$ in. ~ = 60 cycles.
λ_2 = $13\frac{5}{8}$ in. periph. vel. = 4730 ft. per min.

Losses
stator $I^2 R$ = 0.77 kw.
rotor $I^2 R$ = 0.9 "
stator core loss = 0.77 "

total loss 2.44 kw.

Heat runs temperature rise given in ° cent.

Standard motor Fig. 5	Same motor	Same motor	Same motor	Parts of motor
	Housing holes closed with perforated sheet metal $\frac{3}{8}$″ holes on $\frac{5}{8}$″ centres	Housing holes closed with sheet metal	Housing holes closed with sheet metal	
	Yoke openings A. open	Yoke openings A. open	Yoke openings A. closed with cardboard	
18½° cent. rise	22 ° cent. rise	46° cent. rise	74 ° cent. rise	Stator coils
18½	20	48	71	" laminations
15	21	46	71	Rotor cond.
14	21	44	71	" ring
14	20	41	69	" laminations
14	24	39	61	Oil in bearings
		25–30	52–57	Outside of yoke

The following figures, in Table VIII, show how nearly uniform the temperature becomes in the inside of such a machine. It is not the purpose of this paper to enter into the subject of the use of open motors with large sheet-metal cases, or the use of forced ventilation or water cooling, yet there is room for valuable discussion on this point.

A paper to be presented at the 26th annual convention of the American Institute of Electrical Engineers, Frontenac, N. Y., June 28, 1909.

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(Subject to final revision for the Transactions.)

FUNCTION OF FLY-WHEELS IN CONNECTION WITH ELECTRICALLY OPERATED ROLLING MILLS

BY H. C. SPECHT

For all kinds of motor drives and particularly for rolling-mill service, where the load conditions are very unstable, the use of a suitable fly-wheel is of great importance. As is well known, the function of a fly-wheel is to take up the sudden shocks and equalize the unsteady loads as much as practicable in order to produce the cheapest installation and obtain the most satisfactory and economical operation. The smallest size of motor and the minimum capacity of the generating plant are obtained when the action of the fly-wheel is such that the load on the motor is constant and equal to the average of all the loads. To a certain extent this will be impossible in rolling mills, and it will be the problem for the engineer to determine the most suitable size of fly-wheel, motor, and generating plant with the auxiliary equipments.

In reviewing the characteristics of the load curve of a fly-wheel in connection with an induction motor, attention is called to Fig. 1, in which the area $A\ B\ C\ D$ represents a peak load, the ordinates giving the torque in pounds at 1 ft. radius on the shaft of the motor or the mill and the abscissas giving the time of rolling in seconds.

Assume that a constant resistance is inserted in the secondary circuit of the motor and that the motor is carrying all the load until the peak is reached. We will then obtain the torque curve $A\ E$, the section below the line $A\ E$ representing the torque developed by the motor and that above $A\ E$ the torque delivered by the fly-wheel. During this time the speed of the motor has decreased somewhat, thus making it possible for the fly-wheel to deliver part of its stored energy to the driven shaft.

At the end of the peak load, the motor begins to speed up, giving energy back to the fly-wheel, as shown by the torque curve EF. The energy indicated by the area EDF must be equal to the energy indicated by the area $ABCE$, the energy delivered by the fly-wheel.

Since the torque of an induction motor with a constant resistance in the secondary circuit varies almost directly as the slip, an equation for the torque curve AEF may be determined as follows:

Let T_1 = the torque at 1 ft. radius developed by the fly-wheel at the start of the peak load.

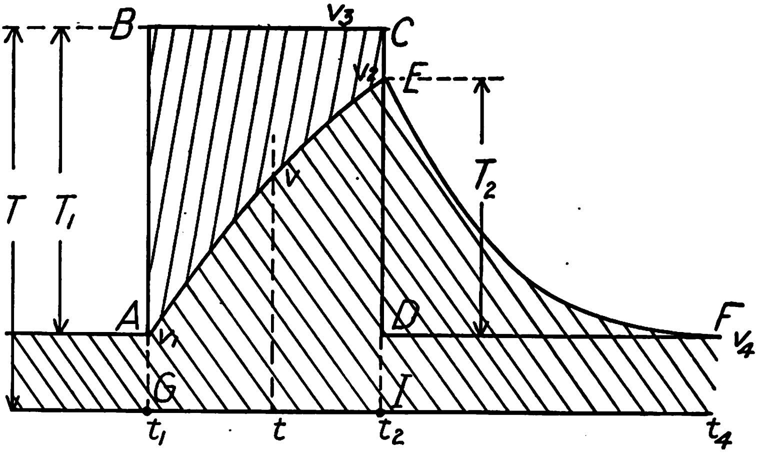


Fig. 1. Showing the relation of the torque of Motor and Flywheel.

T_2 = The accelerative torque developed by the motor at the end of the peak load.

v_1 = the velocity of the motor in feet per second at 1 ft. radius at the start of the peak load.

v_2 = The velocity at the end of the peak load.

v_3 = The velocity if the motor were developing all the torque without the assistance of the fly-wheel.

v_0 = The velocity at synchronism or no-load.

v_4 = The velocity at the beginning of the succeeding peak.

v = The velocity at any time.

t = Time in seconds.

W = Fly-wheel effect; that is, the total weight of the rotating parts multiplied by the square of the radius of gyration.

g = Acceleration due to gravity = 32.2

The equation for the torque curve $A\ E$ during the period of retardation is, then,

$$T_1 - \frac{v_1 - v}{v_1 - v_3}\, T_1 + \frac{W}{g} \cdot \frac{d\,v}{d\,t} = 0$$

or,

$$d\,t = -\frac{W\ (v_1 - v_3)}{T_1\, g} \cdot \frac{d\,v}{v - v_3}$$

integrating,

$$t = -\frac{W\ (v_1 - v_3)}{T_1\, g} \cdot \log \text{nat} \left(\frac{v - v_3}{v_1 - v_3}\right) \tag{1a}$$

or,

$$v = \frac{v_1 - v_3}{e^{\frac{t\, T_1\, g}{W\,(v_1 - v_3)}}} + v_3 \tag{1b}$$

The equation for the torque curve $E\ F$ of the period of acceleration is

$$\frac{v_4 - v}{v_4 - v_2} \cdot T_2 - \frac{W}{g}\ \frac{d\,v}{d\,t} = 0$$

or,

$$d\,t = \frac{W\ (v_4 - v_2)}{T_2\, g} \cdot \frac{d\,v}{v_4 - v}$$

integrating

$$t = -\frac{W\ (v_4 - v_2)}{T_2\, g} \cdot \log \text{nat} \left(\frac{v_4 - v}{v_4 - v_2}\right) \tag{2a}$$

or,

$$v = v_4 - \frac{v_4 - v_2}{e^{\frac{t\, T_2\, g}{W\,(v_4 - v_2)}}} \tag{2b}$$

As examples of the above, Fig. 2 shows several torque curves for different fly-wheel effects and speed-torque characteristics. For simplicity, a continuous cycle of constant peaks of 100,000 lb. has been selected, with half-second periods of duration and half-second intervals.

The fly-wheel effect and the slip for a torque of 100,000 lb. at 1 ft. radius, from which these curves are derived, are as follows:

Curve I—W = 150000, slip at 100000 lb-ft. torque = 10%
" II—W = 300000, slip at 100000 lb-ft. torque = 10%
" III—W = 150000, slip at 100000 lb-ft. torque = 5%
" IV—W = 300000, slip at 100000 lb-ft. torque = 5%
" V—W = 900000, slip at 100000 lb-ft. torque = 10%

It will be noted that curves I and IV are identical; that is, in curve IV, with half the secondary losses or slip and double the fly-wheel effect, the same results are obtained as in curve I with double slip and half the fly-wheel effect. From these curves it can clearly be seen that the greater the fly-wheel effect and the greater the slip for a given torque, the better will be the equalization of loads. When the resistance in the secondary circuit is not kept constant, the foregoing method of determining the torque can be used if the load diagram is divided into sections for which the secondary resistance may be considered constant.

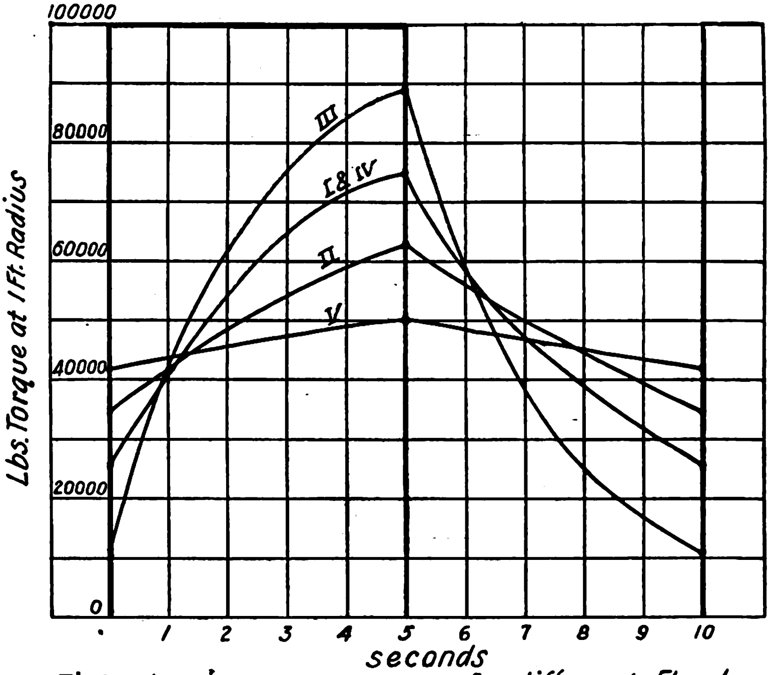


Fig. 2. Showing torque curves for different Flywheel effect and slip

Since the motor must always slow down in speed during the peak loads in order that the fly-wheel may assist it in carrying the load, and since the peaks in all kinds of rolling-mill service vary from pass to pass, it appears that an automatic method in cutting resistance in and out of the secondary circuit of the motor at the proper time would be most desirable. In such a way we could obtain the best equalizing effect and the highest combined efficiency and power-factor.

However, the load conditions in rolling mills are usually such that an automatic control cannot follow the changes of load. For example, in a sheet or a merchant mill where the peaks are quite variable in size as well as in duration and are generally very short, the automatic control cannot be used to advantage. Owing to the time-constant of the automatic controlling devices, the additional resistance may not be inserted at the proper time. This results in the motor at first carrying an excessive load until the resistance in circuit has been increased, when the fly-wheel will assist by delivering part of its stored energy to the shaft. After the peak is over the same sluggishness of the control may prevent the motor from restoring to the fly-wheel all the energy delivered by the latter during the peaks, resulting in a slowing down during succeeding passes. In such a case the automatic control will do more harm than good. Therefore, with such load characteristics the best results would be obtained by having a permanent resistance of the proper amount in the secondary circuit.

In but few rolling mills the periods of peak loads are such that an automatic control can be used to advantage. The duration of all the maximum peak loads must be long enough to allow the controlling devices to act. On the other hand, if the peak loads exceed a certain length of time, an equalization of loads may not be practicable. In this case, the most economical operation would be obtained by running the motor with a small slip and a fly-wheel of sufficient capacity.

In view of the foregoing, it appears that as a general rule for peaks of very short duration (approximately 2 seconds or less), of very long duration (approximately 8 seconds or more), and for extremely variable loads, a permanent resistance in the secondary circuit or a control operated by hand is most desirable. An accurate rule as to the proper kind of control and the size of the fly-wheel can scarcely be given. In each individual case all the possible load conditions should be taken into consideration in order to obtain the best equalization of loads, the highest efficiency, power-factor, etc.

As a rule, the electric manufacturers are forced to submit the lowest-priced outfit with the highest power-factor and efficiency; that is, with secondary directly short-circuited, disregarding the actual working conditions as to the efficiency, power-factor, safety of operation, simplicity of control, etc. What does the efficiency with the secondary directly short-circuited mean to the customer if the motor is not to be run under such conditions?

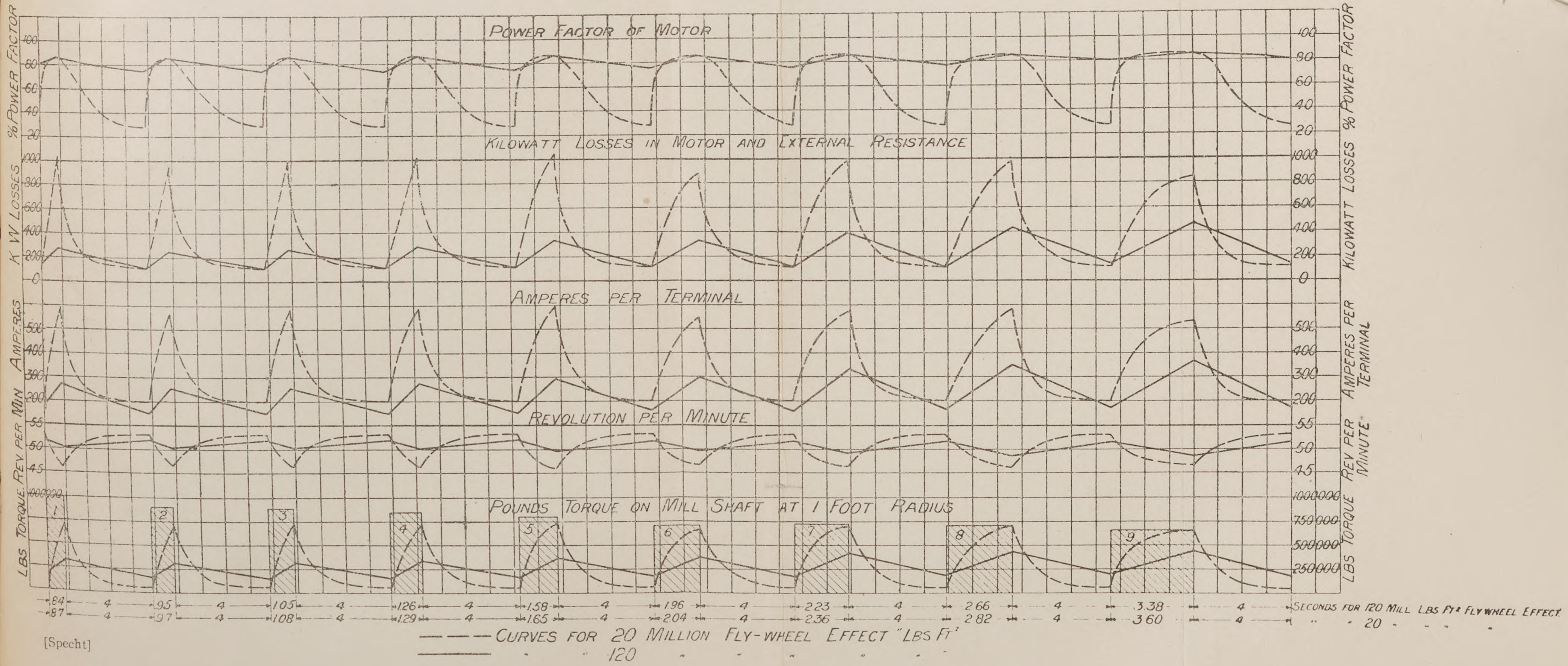
The cost of operation is dependent upon the combined efficiency of the complete cycle. The highest combined efficiency will require, in most cases, a great fly-wheel effect, and it may be necessary to build a separate fly-wheel in addition to the motor. Considering the fact that the fly-wheel masses of the motor are generally moving at very low velocity and that the fly-wheel effect increases with the square of the velocity or the radius of gyration, it is apparent that a greater fly-wheel effect might be obtained without increasing the weight of the complete outfit by the use of a separate fly-wheel. This might also allow a cheaper and mechanically better construction.

On the other hand, when a very great fly-wheel effect is desired in order to equalize the load, it should also be noted that a greater fly-wheel effect will require more time to stop or start or to change over from one speed to another. Therefore, in a case where this is of great importance, a compromise has to be made between the question of equalization and time. It should also be borne in mind that the total time of a complete cycle of rolling differs with the different speed controls.

The conclusion from the foregoing is that the cheapest outfit is not always the most desirable, nor does it always give the lowest operating cost. Even if it requires considerable time to work out the best arrangement in all the details, the entailed expenses will be saved many times in the installation and operation. It is somewhat surprising that in the past no more time has been spent in the careful study of the subject, since the future of the electrification of rolling mills depends so much on the first installations.

As an illustration of how to arrive at the most economical result the writer has selected an example with load characteristics similar to those of a universal plate or rail mill. For the sake of simplicity the example has been limited to the first nine

FIG. 3


POWER FACTOR OF MOTOR
% POWER FACTOR
100
80
60
40
20
KILOWATT LOSSES IN MOTOR AND EXTERNAL RESISTANCE
K W LOSSES
KILOWATT LOSSES
1000
800
600
400
200
0
AMPERES PER TERMINAL
AMPERES
AMPERES PER TERMINAL
500
400
300
200
REVOLUTION PER MINUTE
REV PER MIN
REV PER MINUTE
55
50
45
POUNDS TORQUE ON MILL SHAFT AT 1 FOOT RADIUS
LBS TORQUE
1000000
750000
500000
250000
1
2
3
4
5
6
7
8
9
.84 4 .95 4 1.05 4 1.26 4 1.58 4 1.96 4 2.23 4 2.66 4 3.38 4 SECONDS FOR 120 MILL LBS FT² FLYWHEEL EFFECT
.87 4 .97 4 1.08 4 1.29 4 1.65 4 2.04 4 2.36 4 2.82 4 3.60 4 " " 20 " " " "
CURVES FOR 20 MILLION FLY-WHEEL EFFECT "LBS FT²"
" " 120 " " " " " "

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passes and to two different fly-wheel effects. The data given for this example are as follows:

Pass	Pounds torque at 1 ft. radius	Time in seconds
1	1,000,000	0.82
2	900,000	0.93
3	880,000	1.03
4	840,000	1.24
5	800,000	1.55
6	700,000	1.85
7	720,000	2.17
8	700,000	2.58
9	650,000	3.3

The intervals between passes are four seconds each. The speed is 52 rev. per min. and the supply circuit three-phase, at 6600 volts and 25 cycles. The motor for this speed would, therefore, have 56 poles, which would correspond to a synchronous speed of 53.6 rev. per min. With these data the calculation was made as follows: the average torque and the horse-power for the given load diagram were found to be 261,000 lb-ft. and 2640 h.p., respectively. In arriving at an approximate size for the motor required if the equalizing of loads by the fly-wheel is to be small, the square root of mean square of the loads is calculated, the torque being 418,000 lb-ft. and the horse power approximately 4100 for normal rating. The design for this size of motor gave a fly-wheel effect of approximately 20,000,000 lb. at 1 ft. radius.

Since the peak loads are of short duration, a speed control having a constant resistance in the secondary circuit was selected. The size of the resistance was made such that a 1,000,000 lb-ft. torque on the motor shaft would correspond to 20 per cent slip.

On this basis, the torque curves were drawn in Fig. 3 by means of formulas 1*b* and 2*b*. For these torque curves the corresponding values for speed, amperes per terminal, kw. losses, and power-factor were obtained from the curves shown in Fig. 4, and plotted in the dotted lines shown in Fig.3.

These curves show that the fly-wheel is very much too small to give a satisfactory equalization of loads and that a much larger fly-wheel is required. Since the fly-wheel masses of the rotor are moving with a very low velocity—not over 3000 ft. per minute—and since it will be almost impossible to add sufficient weight to the rotor without making rather a poor design, it is desirable to build a separate fly-wheel with much greater

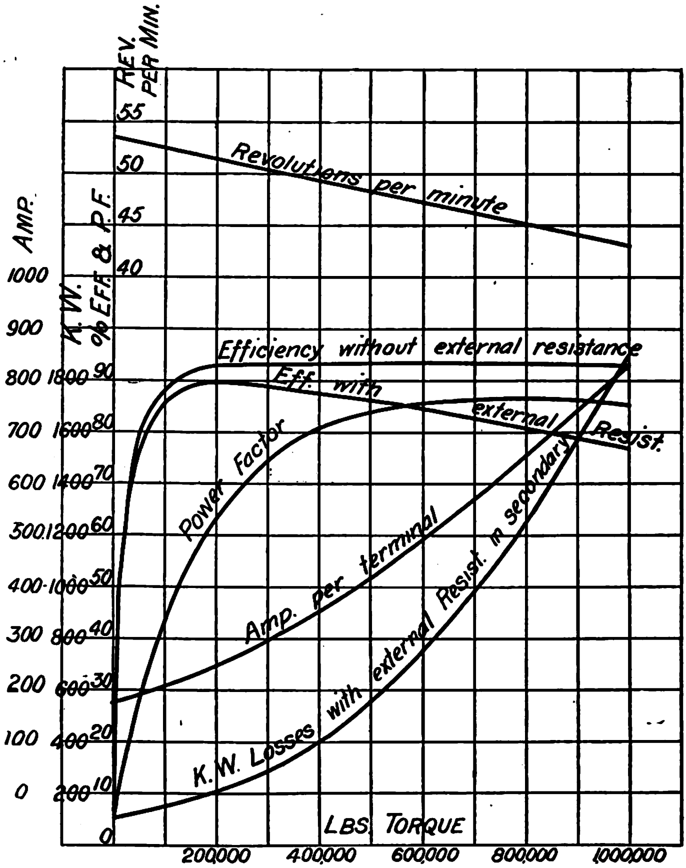

FIG. 4. SHOWING PERFORMANCE CURVES FOR MOTOR WITH 20 MILL. LBS. FT.^{2} FLYWHEEL EFFECT.

fly-wheel effect. One of 120,000,000 lb-ft.^{2} fly-wheel effect was selected. Curves for this value and for a motor with the same slip as the foregoing are shown in Fig. 5 and in full lines in Fig. 3.

Comparing the curves of the smaller and the greater fly-wheel effect shown in Fig. 3, it can easily be seen that the results with the greater fly-wheel effect are very much better in every respect. The power-factor remains nearly constant in comparison with the power-factor for the smaller fly-wheel with which a variation of 28 to 86 per cent occurs during every pass. Comparing further the torques and current values and obtaining from them the square root of the mean squares, we will find

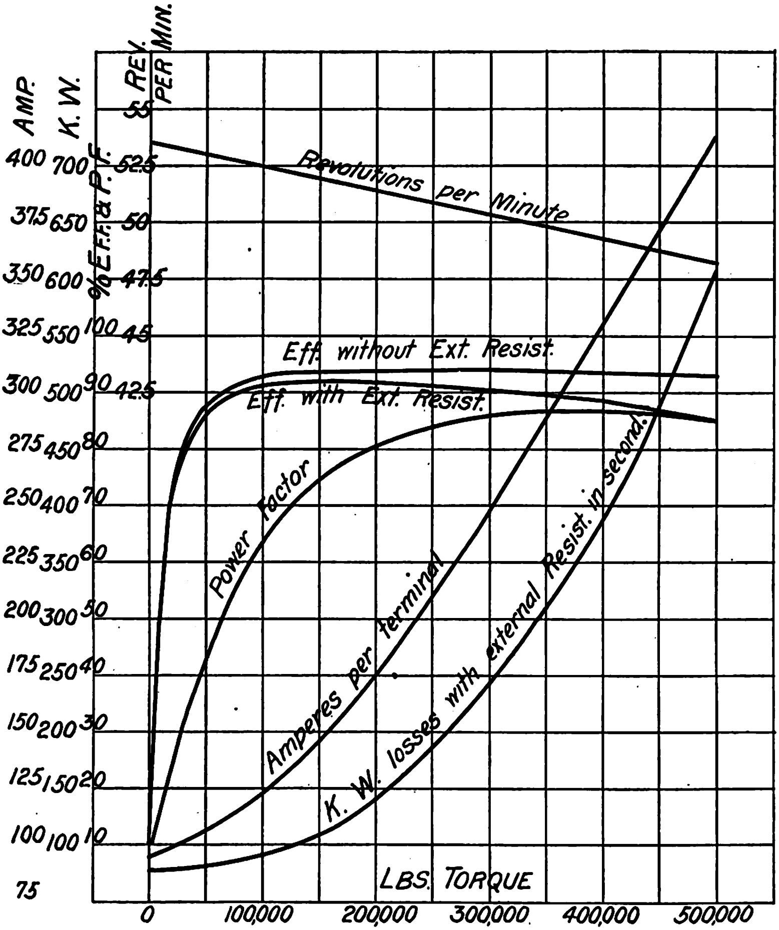

FIG. 5. SHOWING PERFORMANCE CURVES FOR MOTOR WITH 120 MILL. LBS. FT.² FLYWHEEL EFFECT.

that a motor with a normal rating of approximately 2800 h.p. and a pull-out torque of approximately 700,000 lb-ft. would be large enough, whereas, for the smaller fly-wheel, a motor of normal rating of approximately 3700 h.p. and a pull-out torque of at least 1,200,000 lb-ft. would be required.

Further, by integrating the time losses in Fig. 3 and taking their average value per second, we obtain 212 kw. for the set with the larger fly-wheel and 352 kw. for the set with the smaller. The combined efficiency of the motors, including the losses in the external resistances, would then be equal to 90.3 per cent against 84.6 per cent with the small fly-wheel effect.

The total time for one complete cycle of rolling is 51.9 sec. for the large fly-wheel and 52.7 sec. for the small one. However, the time required to accelerate the motor with the greater fly-wheel effect from 0 to 52 rev. per min. or to retard it from 52 to 0, is 58 seconds for a constant torque of 350,000 lb-ft. The time for the motor with the small fly-wheel effect is only one-sixth of this.

With the exception of the foregoing disadvantage, there should be no doubt that the proposition with the greater fly-wheel effect is more economical than the other. The motor can be made much smaller, and even with the heavy additional fly-wheel the total cost for the complete motor outfit might be lower than for the larger motor without the separate fly-wheel. Further, the higher efficiency, the nearly uniform high power-factor and the lower average current make it possible to reduce the capacity of the generating plant and the transmission system, thus increasing the saving. Finally, the higher combined efficiency means also a lower operating cost. It might also be mentioned that with the use of a large fly-wheel to take up the heavy shocks, the motor might be built with a smaller air gap and for higher speed and geared, belted, or roped to the mill shaft carrying the fly-wheel, thereby obtaining a still cheaper motor outfit.

It is not the intention to say that the set with the 120 million lb-ft.^{2} fly-wheel effect in the foregoing example is the final solution. It is simply to show how to treat a motor proposition for rolling-mill drive and what results can be obtained with a large fly-wheel. In order to obtain the best result it would be necessary to try other fly-wheel effects, slips, efficiencies, etc.

If rolling-mill propositions are treated in a manner similar to the above, and further, if advantage is taken of more reliable test data, which may be obtained from installations both here and abroad, there can scarcely be any doubt that the electric drive in rolling mills will be a success.

A paper to be presented at the 26th annual convention of the American Institute of Electrical Engineers, Frontenac, N. Y., June 28, 1909.

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REPULSION MOTOR WITH VARIABLE-SPEED SHUNT CHARACTERISTICS

BY E. F. W. ALEXANDERSON

A characteristic feature of the electrical developments of late years has been the extension of the use of alternating-current to every field where it is practicable. The reasons for this preference for alternating current are so well known that reference need only be made: first, to the advantages of the distribution system; and second, to the fact that the best and most reliable of all motors is the induction motor.

Direct current is used in those cases in which the induction motor would not have the desired characteristics, and the natural consequence is that great efforts have been made to develop alternating-current motors with such characteristics as would enable them to take the place of the direct-current motor. The need most felt was for an alternating-current motor with the characteristics of the direct-current series motor. This requirement has been filled by the repulsion motor, the series motor, and certain modifications of these fundamental types. Another characteristic that was desired was a single-phase motor with constant speed and high starting torque. This requirement has been filled by the Milch motor, the Wagner motor, and some other similar types, all of which are of the repulsion-motor type in starting and run at constant speed as single-phase induction motors.

Although the advantages of alternating current for industrial plants are generally recognized, it is often necessary to recommend the use of direct current because many of the machines that are to be driven require a motor with adjustable speed. The direct-current shunt motor is the only one on the market which fills this requirement. If it is not practicable to have the plant wired for direct current as well as alternating current; all the constant-speed work must be done with direct current, although induction motors would be preferable for this purpose. The investigations and tests described in this paper have been made in order that this need arising in the development of alternating current, may be met by providing a motor with the characteristics of the direct-current shunt machine.

Before entering into a detailed description of any specific form of motor, it may be of interest to present a theory of the alternating-current machine in such a way as to indicate the possibilities of developing a motor with required characteristics.

When an induction motor runs at synchronous speed, the armature winding is stationary in relation to the magnetic field, which is assumed to rotate at a uniform velocity. It is therefore apparent that the conductors do not cut any lines of force and no electromotive forces are induced.

In giving the theory of a motor with adjustable speed, the subject can be made clearer by departing from the theory of the rotating field. If the strength of a rotating field fluctuates so that the maximum strength always occurs when the poles are in a certain position and the minimum strength in another position, the field may be called elliptical instead of a plain rotating field; however, the elliptical shape of the field does not in itself convey any idea as to the reason why the motor should tend to run at any other speed than that of the rotating field.

In the following, the rotating field will be treated as if it were composed of two alternating-current fields at right angles to each other. If an armature with a cummutator of ordinary construction is placed in such a field and two sets of brushes are arranged on the commutator in quarter-phase relation to each other, the following will take place: When the armature is at a standstill, a voltage will be induced between the positive and negative brush of each set, due to the alternating character of the two fields. Field *A* in Fig. 1, will induce a voltage between brushes *B* and vice versa. If the armature rotates at any speed, field *A* will induce an electromotive force between brushes *A*, and this electromotive force will be in opposition to the electromotive force induced by field *B* due to the alternating character of the field. In an ordinary induction motor, the two fields *A* and *B* are of equal strength, and in this case, the electromotive force of rotation will be completely neutralized by the electromotive force of alternation when the motor has reached synchronous speed. The armature has a tendency to run at a speed at which the induced currents are a minimum. All motors of this kind have only one free running speed, which is that of synchronism. This is true with motors of the commutator type, as well as the squirrel-cage and collector type, provided that the brushes are short-circuited.

If the condition which determines the speed of an alternating-current motor should be formulated broadly, the following might be stated:

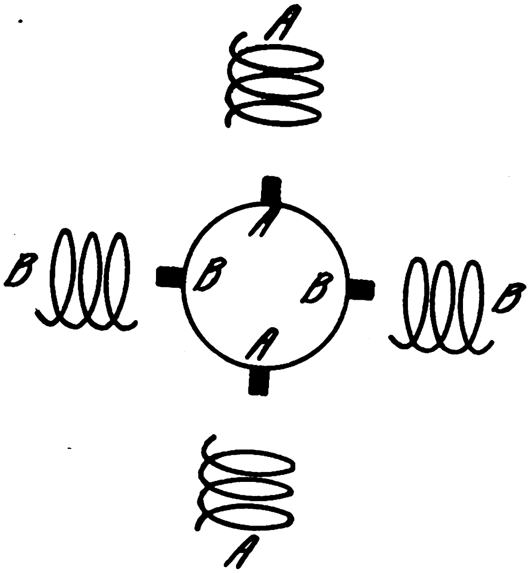


Fig. 1

The motor tends to run at a speed at which the sum of all the electromotive forces in each of the armature circuits is zero. The electromotive forces to be considered are particularly the electromotive force of rotation and that of alternation; these two electromotive forces are always in opposition. A third electromotive force may be induced artificially by impressing a voltage on the circuit from outside.

The two sets of brushes in a repulsion motor of the compensated type may be classified as the main brushes and the exciting brushes; the main brushes carrying the energy current of the armature, the exciting brushes carrying the magnetizing current. If the main brushes as well as the exciting brushes are short-circuited, the motor will act like a single-phase induction motor. A practical modification of this motor has been developed by Milch, its principal feature being the power-factor regulation accomplished by impressing a suitable voltage on the exciting brushes. The impressed voltage is out of phase with the electromotive force of alternation and the electromotive force of rotation in the same circuit, so that it has nothing directly to do with the speed of the motor, which remains a constant-speed machine. It should be mentioned here that it is found advantageous in all commutator motors that will be described here, single-phase as well as three-phase, to introduce a correction of the power-factor like the one used in the Milch motor. However, the power-factor regulation has nothing to do with the theory of the speed variation, and reference to the power-factor regulation will, therefore, be omitted from the description of each particular form of motor in order that a more comprehensive explanation of the speed regulation may be given.

It is apparent from the preceding that the equilibrium of voltages that exists at synchronous speed when both sets of brushes are short-circuited, can be disturbed by introducing a voltage from the outside into either the circuit of the main brushes or the circuit of the exciting brushes; but it remains to be shown that in doing so another equilibrium can be established by changing the speed of rotation.

By a simple calculation, it can be shown that the relation between speed and field strength and the impressed voltages can be expressed as follows:

$$\text{Speed} = \text{Synchronous speed} \sqrt{\frac{E+e}{e}}$$

$$\frac{F_1}{F_2} = \frac{\text{speed}}{\text{synchronous speed}}$$

where E is the voltage impressed on the stator winding reduced to number of turns in the armature, and e is the voltage impressed on the armature. F_1 and F_2 are the two components of the field in the axis of the exciting brushes and the axis of the main brushes, respectively. The voltage which is impressed on the armature may be either positive or negative, and consequently the speed can be regulated below synchronous speed as well as above synchronous speed. The method for speed variation described can be classified as armature control, because the functions correspond to those of a direct-current shunt motor when the speed is varied by raising and lowering the line voltage.

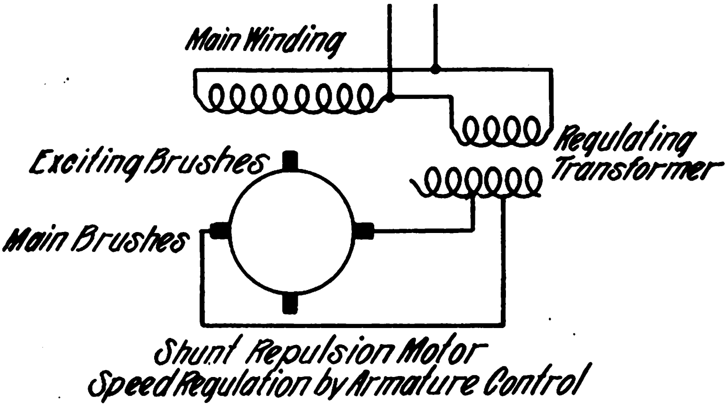

Main Winding
Regulating Transformer
Exciting Brushes
Main Brushes
Shunt Repulsion Motor
Speed Regulation by Armature Control

FIG. 2

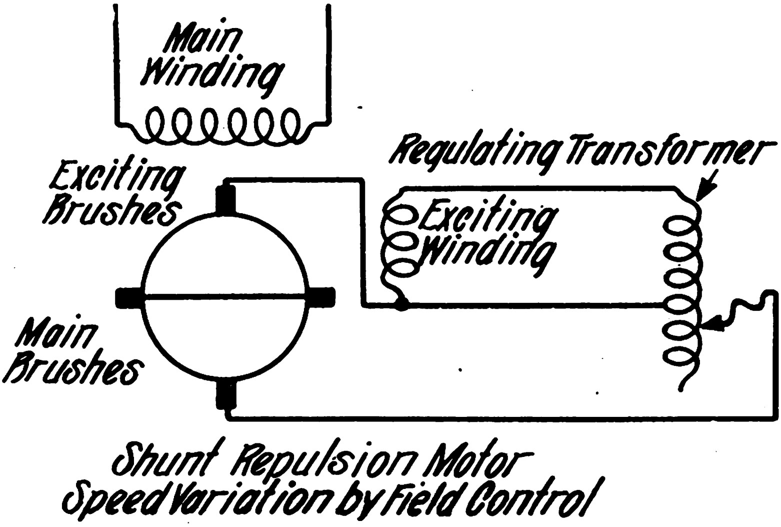

Main Winding
Regulating Transformer
Exciting Winding
Exciting Brushes
Main Brushes
Shunt Repulsion Motor
Speed Variation by Field Control

FIG. 2A

The second method for varying the speed of the repulsion motor follows logically. As shown in Fig. 2, the short-circuit is maintaned on the main brushes, while an external voltage is impressed upon the exciting brushes. In order to make the impressed voltage effective for speed variation, it should be in phase with the voltage of alternation and the voltage of rotation of the same circuit. These voltages in the exciting circuit are out of phase with the line voltage and, consequently, the line voltage cannot be used for varying the speed; however, if the motor has an exciting winding, like a plain repulsion motor, in addition to the exciting brushes, a voltage is found on the terminals of the exciting winding which has a suitable phase to be used for speed variation by field control.

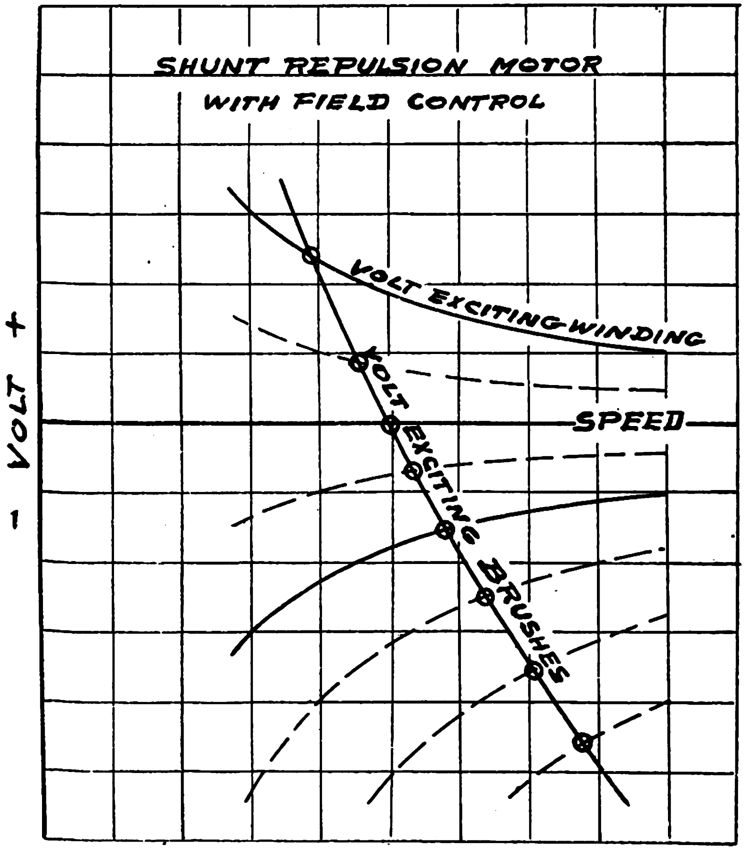


FIG. 3

The equilibrium of voltages is reached by a combined change of field strength and speed, for the same reason as in the case of armature control; however, the functions of the two fields are different; the entire energy supply is introduced through the stationary winding and the speed variation is obtained by variation of the torque-producing field, in the same way as the speed varies in a direct-current shunt motor with field control.

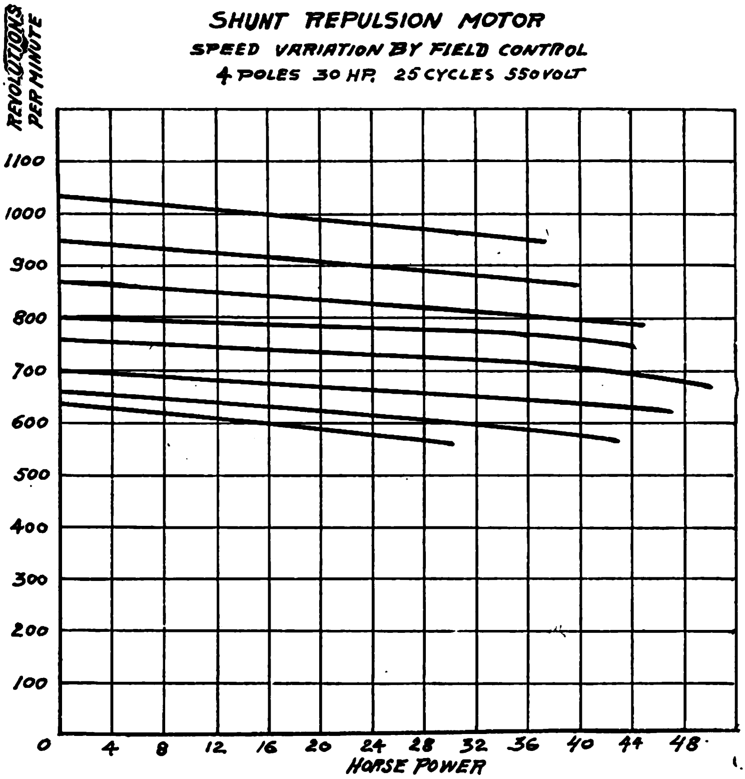


FIG. 4

The relation of voltages which gives the equilibrium in the two brush circuits is not quite as simple to figure out as is the case of armature control; because the voltage impressed upon the brushes for the sake of speed variation is not derived from a constant source of potential, but from a winding which delivers a voltage that is in itself a function of the speed. However, the relations become comparatively simple by returning to the theory of the plain repulsion motor and plotting curves for the voltage that would naturally occur at the exciting winding and the exciting brushes at different speeds. The voltage of the exciting winding is always positive, but varies inversely with the speed;

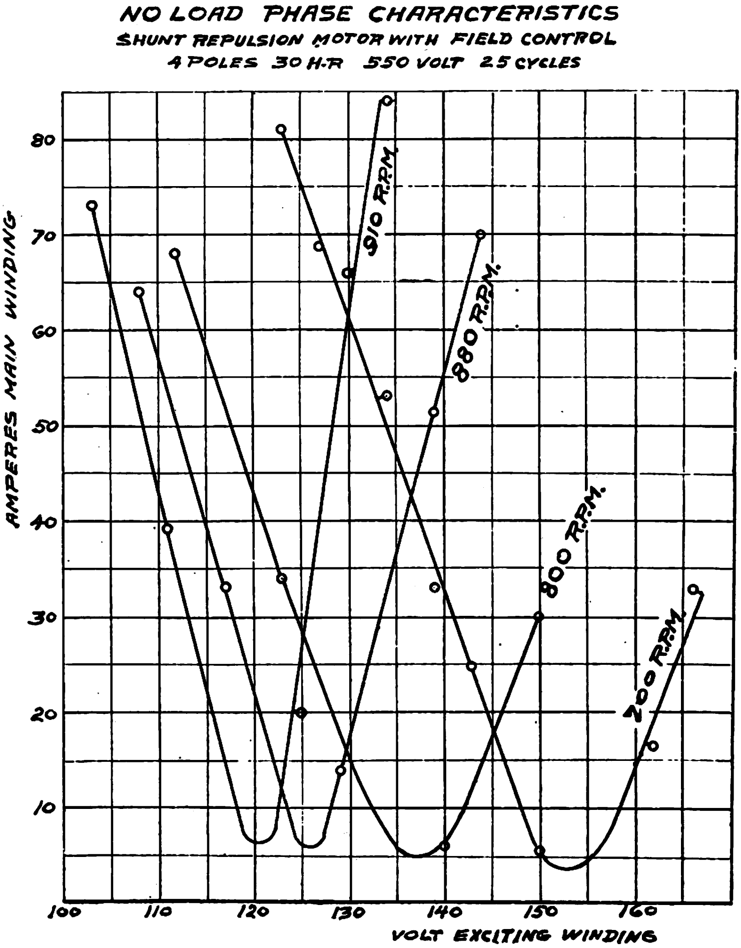
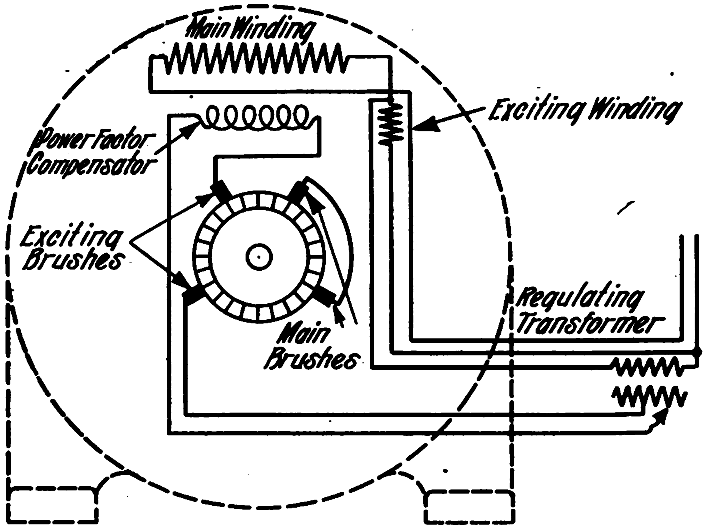


Fig. 5

while the voltage of the exciting brushes is positive below synchronous speed and negative above synchronous speed. Fig. 3 shows curves of these voltages plotted on the same sheet. Only one curve is shown for the voltage of the exciting brushes, while the voltage of the exciting winding is plotted on the positive as well as on the negative side. The dotted curves indicate different voltages that may be derived from the exciting winding by the use of a step-up and a step-down transformer. The points marked in the intersections between the curves indicate equilibrium of voltages that may be obtained at different speeds by impressing on the exciting brushes the different voltages derived from the exciting winding.

The tests, which have been made on a 30-h.p., 25-cycle motor and a 3-h.p., 60-cycle machine in order to demonstrate the possibilities of the alternating-current shunt motor, confirm entirely the theory given above. The curves in Figs. 4 and 5, which may be considered as typical, show the results of test of the 30-h.p., 25-cycle motor. Fig. 2 shows a diagram of connections giving the principal features of armature control as well as field control. The connections used for controlling the power-factor have purposely been omitted from these diagrams because they are apt to make confusion and have nothing to do with the point that is to be illustrated. A practical control diagram for the motor with field control is shown in Fig. 6.



Shunt Repulsion Motor with Field Control

FIG. 6

The power-factor of any commutator motor with shunt characteristics, single-phase as well as three-phase, can be regulated in a manner similar to that of a synchronous motor. The functions of the power-factor regulation are the same as in the synchronous motor and can be best understood if they are described from the same point of view. The power-factor characteristics of a synchronous motor are usually illustrated by a curve showing the leading and the lagging current taken by the motor at no load with different field excitations. This curve is illustrated in most treatises on the synchronous motor and is recognized by a characteristic V shape. Fig. 5 shows the corresponding V-shaped phase characteristic for the shunt repulsion motor.

While a synchronous motor has only one no-load phase characteristic, the variable-speed shunt repulsion motor has one curve for each setting of the speed; in other words, the power-factor can be varied at will at each speed by adjusting the excitation. In the commutator motor, as well as the synchronous motor, the power-factor regulation consists in superimposing a wattless current upon the current that would otherwise be taken by the motor. It is known from the theory of the synchronous motor, that the power-factor can be maintained practically at unity between no load and full load with one fixed excitation, provided the excitation has been adjusted for the average load. The same is the case with the commutator motor. The regulation of the field for the purpose of adjusting the power-factor is accomplished in the commutator motor by a transformer or a coil in the stator winding, connected so as to introduce a fraction of the line potential in the exciting circuit. By varying the voltage introduced in this way, the amount

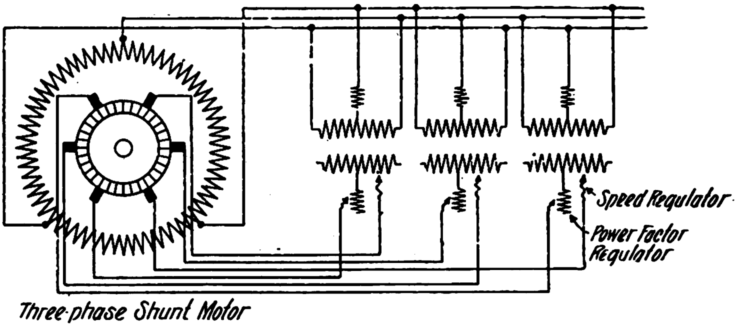


FIG. 7

of wattless current can be regulated, as shown in Fig. 5. The complete diagram for the shunt repulsion motor with field control, illustrated in Fig. 6, shows the feature of power-factor regulation introduced by a coil of the stationary winding.

In connection with this subject, it will undoubtedly be of interest to refer to the possibilities of the three-phase motor with shunt characteristics. The possibility of such a motor was demonstrated theoretically by Georges about ten years ago, and tests of such a motor were made several years ago by Eichberg and Alexander. The speed variation of the Georges three-phase shunt motor is obtained by maintaining a constant field and adding or subtracting voltage to the armature circuit. The power-factor of the three-phase shunt motor can be regulated in the manner described above for the single-phase motor, and the comparison with the synchronous motor is applicable. Fig. 7 shows a diagram of the three-phase shunt motor with power-factor regulation.

In the theory given above for the alternating-current shunt motors, it has only been attempted to indicate the general principles, and the scope of this paper does not permit of entering into the details of application. However, it may be stated that speed variation by armature control is particularly applicable to those cases in which the torque increases with the speed, and field control to those cases in which the torque decreases with the speed. With armature control a speed variation can be obtained of 3 to 1; whereas with field control the variation is limited to a range of from 1.5 to 1. It will not be attempted to compare the merits of the three-phase and single-phase shunt motor; however; it may be stated as the impression of the author that the single-phase shunt motor will be preferred on account of the greater simplicity of control.

A paper to be presented at the 26th annual convention of the American Institute of Electrical Engineers, Frontenac, N. Y., June 28, 1909.

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(*Subject to final revision for the Transactions.*)

ALTERNATOR FOR ONE HUNDRED THOUSAND CYCLES

BY E. F. W. ALEXANDERSON

Before entering into a description of the form of generator dealt with in this paper, it may be of interest to give a short review of the history of the high-frequency alternator. Heretofore the 10,000-cycle machine has represented the highest frequency in commercial use. Such a machine was developed by one of the electrical manufacturing companies in 1900 and a number of them are now in service. A similar machine for 10,000 cycles was described by Lamme in a paper before the Institute in 1904.* Reference may be made particularly to a paper by Dudell read before the Physical Society of London, giving a synopsis of his work with this kind of apparatus and describing the experiments made by him.

In 1904 when the author began to develop for Professor Fessenden, an alternator which should have a frequency of about 100,000 cycles and an output sufficient for commercial work in wireless telegraphy, not much confidence was placed in the possibility of constructing such a machine. The doubts expressed in the discussion of Dudell's paper as to the practical application of such machines to wireless telegraph work seemed quite just, in view of the fact that the highest frequency that had been produced with any appreciable output was 10,000 to 15,000 cycles, while Dudell's machine, which had been worked up to 120,000 cycles, had an output of a fraction of a watt.

Since then three machines of the design described in the following pages, and referred to in several papers by Professor Fessenden, have been placed in service. In this paper there will be described a perfected form of the same general type, rated at 2 kw. and 100,000 cycles.

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* Transactions A.I.E.E., 1904. Vol. XXIII. p. 417.

Early types. The stages of development which led to the present type of machine were substantially the following:

In view of the special precaution which had to be taken to reduce the core loss in the alternator built for 10,000 cycles, it was natural in the first attempts at building a machine for 100,000 cycles to try to eliminate the iron in the armature.

The first machine built was a model with a revolving armature of the Ferranti type, 3 in. in diameter. The experiment was encouraging, inasmuch as it demonstrated the possibilty of generating an appreciable amount of power at 100,000 cycles, but the machine could never be brought up to a corresponding speed on account of mechanical difficulties. The armature had 200 conductors consisting of 100 U-shaped phosphor-bronze wires anchored in insulated segments clamped in the rotating body. As long as the machine was run at no load, it acted comparatively well. The centrifugal force and air pressure on both sides of the wires seemed to keep them away from the stationary pole faces; but as soon as the field was applied the magnetic action on the current in the conductors was sufficient to distort the wires so that they would strike the poles and break.

From this experience it was apparent that a successful machine must have a stationary field winding as well as a stationary armature and that the armature should not contain any iron. The outcome of these conditions was a type of machine illustrated in Fig. 1. The armature is made of wood and the two rotating discs form a complete magnetic circuit which is energized by a stationary field coil suspended inside the armature between the discs. In connection with this machine a number of mechanical problems were to be solved, which will be referred to when describing the latest form of the alternator. The chief reason why this machine could not be considered as the final development was the fact that the rotating discs could not be made symmetrical. Owing to this fact the centrifugal force at high speed changed the shape of the discs in such a way that the air-gap between the field and the armature was increased; the result being that the voltage of the generator did not increase in proportion to the speed, but reached a maximum at about 60,000 cycles and decreased at higher speed.

Type of construction. Fig. 2 shows the construction arrived at in a machine recently completed. As there was a question whether it was practicable to use an iron armature at a frequency of 100,000 cycles, the machine was built with two kinds of armatures for trial, one of iron and one of the winding placed in wood. The iron proved to be preferable, giving a higher output and a better mechanical structure. The success of the iron armature is largely due to the fact that the volume of iron subject to alternating flux is extremely small. The main part of the laminated armature carries a constant flux, while the pulsating flux occurs only in the teeth that separate the armature conductors.

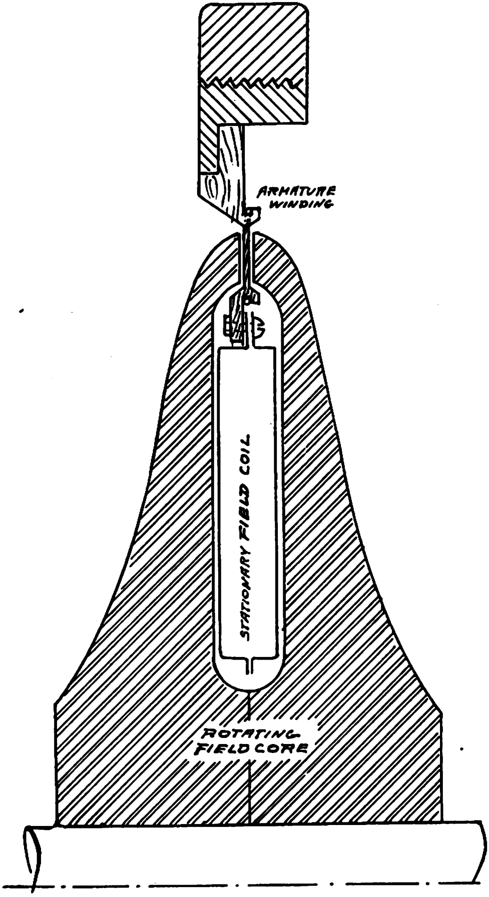


Fig. 1

The alternator shows in every way the same characteristics as a generator of moderate frequency. The following are the constructional data of the machine: the armature has 600 slots with one conductor per slot of 0.013 copper wire, triple-silk covered, and varnished. The wire is wound in a continuous wave up and down in the successive slots. The rotating field has 300 projections, which as the machine is of the inductor type, correspond to 600 poles for a machine of the ordinary alternate-pole type.

It appears from the electrical characteristics that the output of the generator depends largely upon the air-gap clearance, because the voltage of the machine is nearly inversely proportional to the air-gap. The characteristic curves have been given at an air-gap of 0.015 in. but the output of the generator can be doubled if a smaller air-gap be used; in fact the machine has been operated with an air-gap as small as 0.004 in., though such a clearance would not be practicable for continuous operation. In view of this condition it is desirable to regulate the air-gap so as to offset any wear in the bearings, and to select the gap which is suitable for the work to be done. If the machine

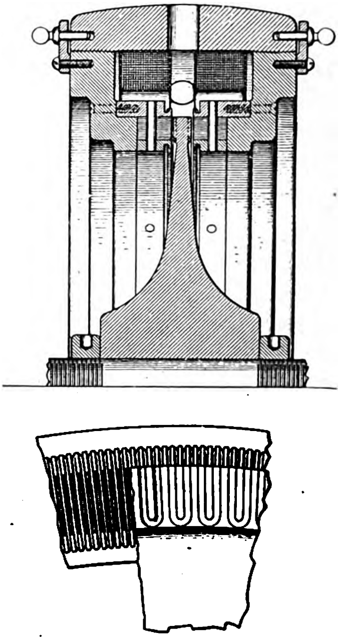


FIG. 2

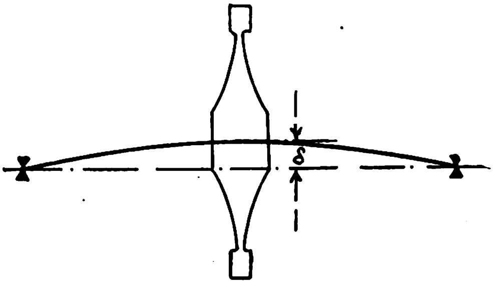
is to be operated continuously without attention, a comparatively large clearance is necessary, while for a special experiment in which higher power is required a small gap may be used.

The sensitiveness of the air-gap regulation is one of the reasons why, instead of using the usual drum winding construction of the armature, the winding was applied on a radial face, as shown in Fig. 2. The armature is mounted on a frame that is threaded into the stationary field frame, and the air-gap can be set exactly by screwing the armature tight against the disc and then moving it back a distance corresponding to the desired clearance. For this purpose the stationary frame is provided with a scale, so that rotating the armature on its thread one division corresponds to one thousandth of an inch change of the air-gap.

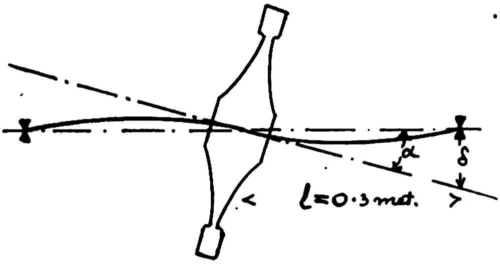
Flexible shaft. At a speed of 20,000 rev. per min., it would not be practical to use a rigid shaft as in ordinary machines. It was therefore necessary to adopt the principle employed in a well-known steam turbine, that of a flexible shaft which allows the disc to revolve round its exact mass center, thus avoiding any strain on the bearings due to centrifugal force. In a turbine of this type designed for a speed of 20,000 rev. per min., the shaft is very thin, about the size of a lead pencil, but not very long. A shaft of such proportions would not be suitable for the alternator in which the exactness of the air-gap is essential and the disc is subject to the magnetic attraction between field and armature. The shaft of the alternator must have not only considerable stiffness, in order to keep the disc in an accurate position, but also sufficient flexibility to allow the rotating disc to adjust itself to its own mass center. To meet these requirements the shaft is designed like a stiff spring with uniform strength so as to obtain maximum work out of the material without exceeding the elastic limit in any part. It has a diameter of 1.25 in. in the middle and 0.625 in. at the ends, the length between the centers of bearings being 28 in.

When the machine is brought up to speed, severe vibration occurs at two distinct critical speeds, one at 1700 rev. per min. and the other at 9000 rev. per min. The vibration increases gradually when the machine approaches the critical speeds. When the vibration has reached its maximum, it ceases suddenly and the machine runs smoothly and with surprisingly little noise, indicating that the disc has fallen into step with itself, so to speak, and is rotating around its own mass-center. The critical speed, which can be predetermined approximately from the design of the shaft and the disc, occurs when the natural vibration of the shaft with the disc coincides with the revolutional speed.

The first point of resonance is the one at which the shaft vibrates like a string, as shown in Fig. 3. The spring force of the shaft tending to hold the disc in its original position is proportional to the deflection from the same position.



VIBRATION IN FIRST CRITICAL POINT



VIBRATION IN SECOND CRITICAL POINT

FIG. 3

Let the deflection $= \delta$
The spring force $= P$
Hence $P = k\,\delta$

in which k is a constant corresponding to the stiffness of the shaft. The constant k can be determined by calculating the deflection of the shaft from its dimensions. The result of such a calculation gives $\delta = 0.0024\ P$ cm. or 0.000024 meters, in which

P is expressed in kilograms. The weight of the disc is 13.6 kg. and the mass $= m = \frac{13.6}{9.8}$.

The equation for resonance in the first critical point is derived by assuming that the shaft swings as a string with a weight in the middle. In order to define the condition for resonance, it is assumed that the disc is brought out of center by an arbitrary amount δ. The condition for mechanical resonance occurs if the centrifugal force of the mass of the disc rotating at a radius δ is equal to the centripetal force created by the deflection of the shaft to the amount δ from its normal shape.

Centrifugal force $= m\,\delta\,\omega^2$

Where ω is the angular velocity.

The spring force of the shaft has been designated P

$$m\,\delta\,\omega^2 = P = \frac{\delta}{0.000024}$$

$$\text{and introducing } m = \frac{13.6}{9.8}$$

$$\frac{13.6}{9.8}\,\delta\,\omega^2 = \frac{\delta}{0.000024}$$

$$\omega^2 = \frac{9.8}{13.6 \times 0.000024}$$

$$\omega = 173$$

Rev. per sec. $\frac{\omega}{2\pi} = 27.5$.

Rev. per min. 1650.

The second harmonic is the one at which the disc vibrates around an axis vertical to the shaft and the shaft assumes an S shape. The momentum exerted by the spring force on the disc is proportional to the angular deviation of the disc.

The relation is $P\,l = k\,\alpha$.

The constant k can be derived from the dimensions of the shaft. In this case

$$k = \frac{l^2}{0.000024} = \frac{0.3^2}{0.000024} = 3750$$

The inertia of the disc for rotation around an axis vertical to the shaft may be designated I. In this case

$I = 0.0052$ expressed in meters and kilograms.

The equation for mechanical resonance is

$$I\,\omega^2 = P\,l$$

in which ω is the angular velocity.

Substitute $P\,l = k\,\alpha = 3750\,\alpha$

$$I\,\alpha\,\omega^2 = 3750\,\alpha$$

$$\omega^2 = \frac{3750}{0.0052}$$

$$\omega = 850$$

$$\text{Rev. per sec.} = \frac{850}{2\,\pi} = 136$$

Rev. per min. = 8200.

A number of mechanical features which have been the principal problems in the development of this machine are described in the following.

Method of drive. The first machine built was belt-driven. After a good deal of experimenting with different kinds of belts and pulleys, it was found feasible to run the machine at 15,000 rev. per min., corresponding to 75,000 cycles. However, it also became apparent that this method of driving could not be accepted for practical use, so that the later machines have been equipped with gears. Although these gears are designed for reduction of speed, they appear to work satisfactorily when the action is reversed. The gear ratio is 10 to 1.

Revolving Disc. The disc is designed so as to have uniform stresses in all parts and consequently the greatest possible margin of safety. The disc is made of chrome-nickel steel with an elastic limit of about 200,000 lb. per sq. in. At a frequency of 100,000 cycles the speed is 20,000 revs. per min. The diameter of the disc being one foot, the peripheral speed is 1,000 feet per second or 700 miles per hr.; in other words, the disc would roll over to Europe in 4 hr. The centrifugal force of the material in the edge of the disc is 68,000 times its own weight, but due to the shape of the disc, which is designed for maximum strength, the stresses are only 30,000 lb. per sq. in., giving a factor of safety of 6.7 to 1.

Heating and air friction. If it be born in mind that the disc has 300 teeth on each side spaced at a distance of 0.125 in. and that these teeth pass the face of the stationary armature at a rate of 1000 ft. per sec. with a clearance of 0.015 in., it can be readily understood that the air friction in the gap must be considerable. It was found that the machine heated up excessively due to air friction, but this has been overcome by filling the slots with non-magnetic metal so that the disc offers a perfectly smooth surface. Then another difficulty was encountered owing to centrifugal force acting on the fillers, each of which is subject to a centrifugal pull of 80 lb. During some of the first attempts, when the slots were simply filled with hard solder, it happened that some of the fillers broke loose. It was interesting to notice that an unbalancing centrifugal force of 80 lb., which would have been enough to bend the shaft at standstill, did not effect the machine, which, in every case, continued to run as if nothing had happened. In the final construction, in which the fillers are anchored so as to stand the strain, they consist of U-shaped phosphor-bronze wires supported directly by the steel teeth so that the solder is needed only to fill the joints.

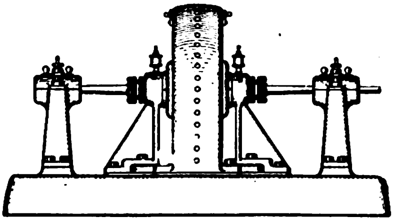
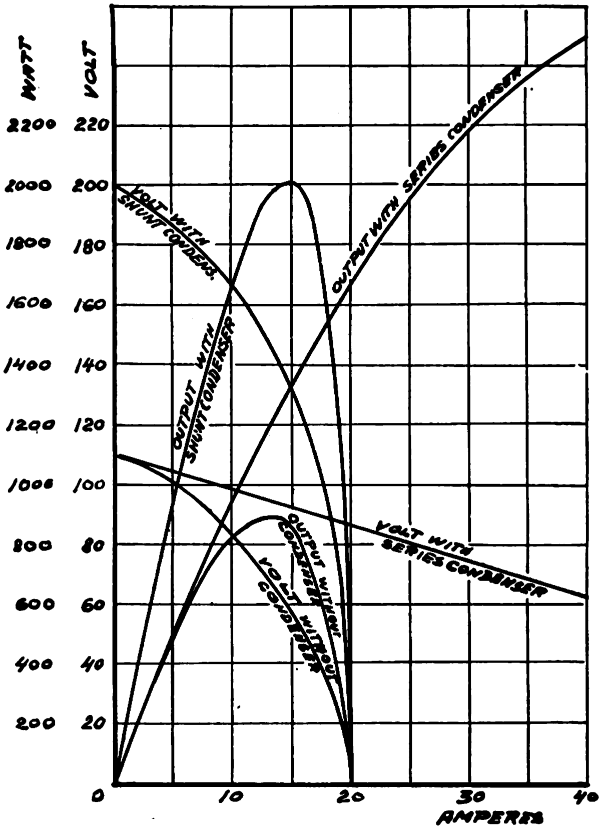


Fig. 4

Bearings. The generator has two sets of bearings as shown in Fig. 4. The outside bearings support the weight of the revolving parts and are fed with a continuous stream of oil supplied by a pump. With this system of lubrication, the machine can run continuously at full speed with a temperature rise of the bearings of only 5 degrees above the temperature of the oil in the tanks. The necessity of the continuous oil feed is demonstrated by the fact that the temperature of the oil in the tank reaches 20° above the surrounding air.

One of the functions of the middle bearings is to prevent excessive vibrations when the shaft passes the speeds of mechanical resonance. During normal operation, the shaft does not touch the middle bearings, which are bored out to give 1/64 in. clearance; at the critical speed, however, the shaft touches the bearings.

The end-thrust of the shaft is taken up partly on the middle bearings and partly on the end bearings. If the air gaps on both sides of the disc were not equal, the magnetic end thrust might be considerable, but with this arrangement of divided end thrust the adjustment seems to be to a certain extent automatic. If the disc has a tendency to move over to one side due to a difference in size of the air-gaps, the corresponding middle bearing will heat up and the same side of the shaft will expand longitudinally, thereby relieving the middle bearing as well as correcting the air-gap.



REGULATION CURVES
2KW 100000 CYCLE ALTERNATOR

FIG. 5

Electrical characteristics. A generator of this kind is always used in connection with a capacity, which is located either in the aerial, as in the case of wireless telegraphy, or in a condenser of suitable capacity used in order to obtain the proper tuning. The best method of showing the characteristics of the generator, without reference to any certain application, is to assume the load to be non-inductive and use a condenser of a fixed capacity as an attribute to the generator. The most typical performance of the generator operating in conjunction with a condenser is the one in which the condenser has an impedance equal to the inductive impedance in the generator winding and is connected in series with the generator. This combination gives the generator a maximum output for any load. A condenser arranged in this way considerably increases the useful performance of the generator and should be regarded as a part of the generating outfit. The tests of the alternator

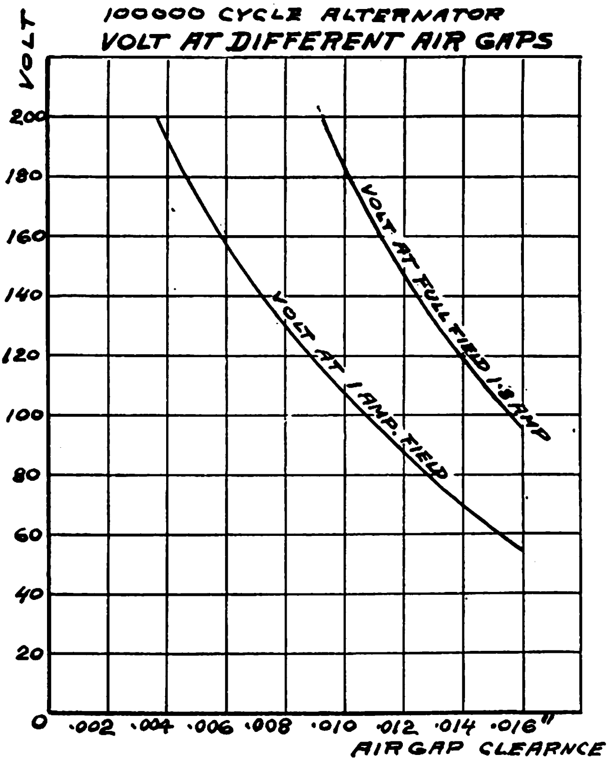


FIG. 6

described here show that the reactance of the armature winding is 5.4 ohms at 100,000 cycles. The condenser which ought to be used in connection with the machine at the same frequency should have the same impedance expressed in ohms. If the capacity is expressed as usual in microfarads, it should be

$$C = \frac{1}{5.4 \times 2\pi \times 100{,}000} \text{ farads}$$

$$= \frac{10}{5.4 \times 2\pi} = 0.3 \text{ microfarads}$$

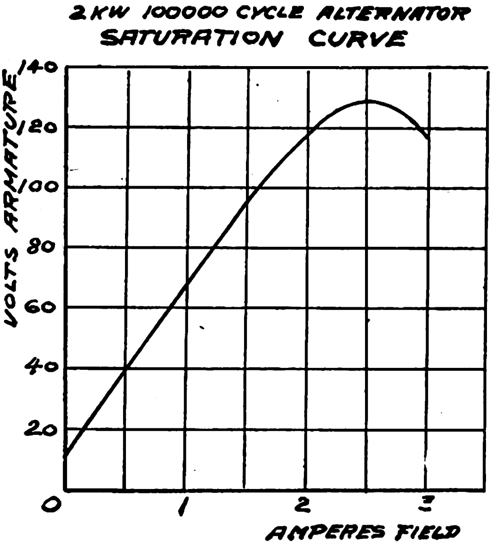


FIG. 7

The vector diagram for the voltages of the different parts of the circuit at full load is shown in Fig. 5. From this diagram it appears that the combination of alternator and condenser gives the same terminal voltage at any load as would a generator which had the same electromotive force and the same ohmic resistance but no inductive drop. In other words, the condenser completely offsets the reactance of the winding, and the regulation is determined entirely by the ohmic resistance.

Tests, as well as practical use of these machines for wireless telegraph work, have shown that the commercial output of the alternator is limited by heating of the armature winding. In building these alternators for practical purposes, the need for a commercial rating of the machines has already been realized. The basis for rating which has been adopted for these machines

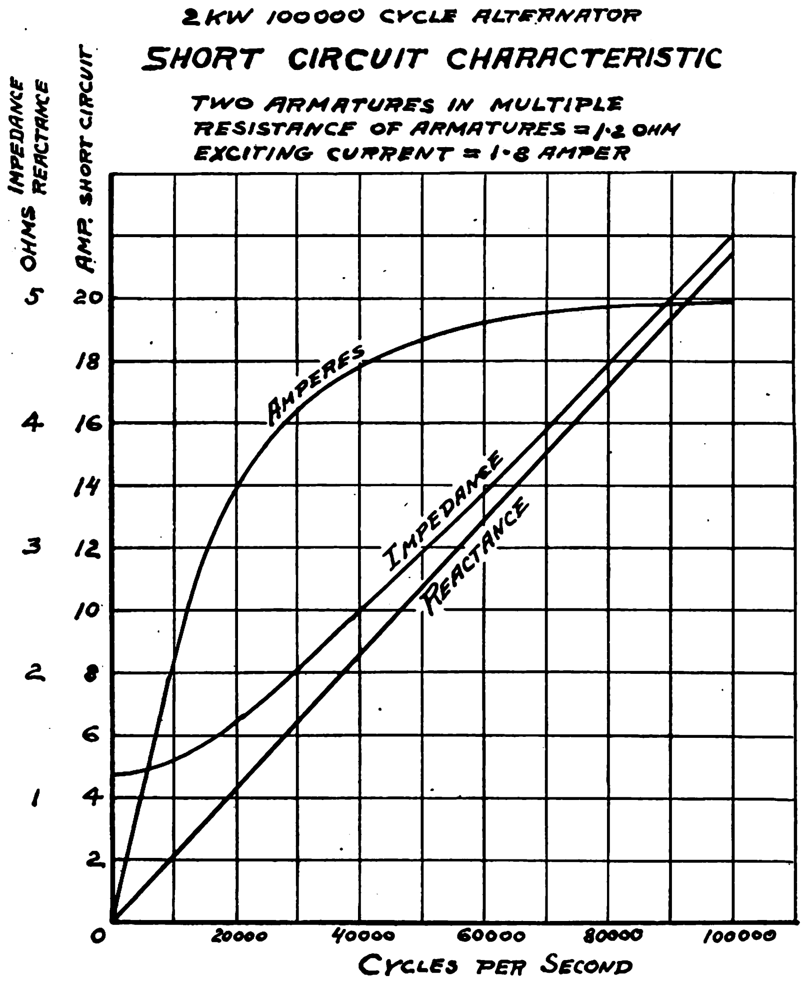


FIG. 8

is illustrated by the rating of the 2-kw., 100,000-cycle alternator.

The characteristics of the machine as given by test are the following:

No load voltage, 110.

Ohmic resistance, 1.2.

Short-circuit current, 20 amperes.

Continuous capacity at 45 degrees rise, 30 amperes.

From the above data, it is apparent that the alternator cannot be operated up to its full thermal capacity without a condenser, and in selecting a condenser the capacity is regulated so as to compensate for the inductance of the winding as described. Under these conditions, the maximum continuous load of the alternator is 70 volts and 30 amperes or 2.1 kw. The commercial rating has therefore been made 2 kw.

It may be of interest to note that the product of the short-circuit current and the no-load voltage is 2.2 kilovolt-amperes equal to the full load-capacity as determined by heating . However, the short-circuit current would not be a suitable basis for commercial rating; because the thermal rating depends entirely upon the ohmic resistance of the winding, while the short-circuit current is nearly independent of the resistance.

It would undoubtedly be of theoretical interest to be able to determine the properties of the iron core at the high frequencies dealt with in this generator. A test made at 60,000 cycles may be referred to for this purpose. The power required to run the whole set without excitation at the corresponding speed was 1340 watts and the additional power required to drive it at the same speed with full field was 330 watts. The only conclusion that can be drawn from this test is that the core loss is not higher than 330 watts. The main part of this loss is probably due to increased bearing friction by magnetic end thrust. By a more delicate laboratory test, it might be possible to separate the additional friction from the core loss, but the above is the only data that are available at present.

Regarding the possibilities of building high-frequency alternators of higher output, it may be mentioned that a machine for 50,000 cycles is being constructed of such dimensions that an output of 35 kw. can be expected. At the present state of the art, however, it is safer to build the machine first and determine its rating after it has been tested.

The question of whether machines can be designed for frequencies still higher than 100,000 cycles cannot be decided offhand. Considering, however, that the present generator has a large margin in the mechanical strength of the revolving disc as well as in the length of the air-gap, etc., it appears probable that still higher frequencies can be reached by direct generation with revolving machinery.

A paper presented at the Cleveland Section of the American Institute of Electrical Engineers, February 8, 1909.

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(*Subject to final revision for the Transactions.*)

THE PURCHASE OF FUEL ON A BRITISH THERMAL UNIT BASIS.[1]

BY LAWRENCE P. CRECELIUS.

The boiler plant of the traction company which operates the street-car system of Cleveland, Ohio, is representative of modern practice in both the nature of the equipment installed and the means employed in handling and firing coal. Of the total cost of manufacturing a kilowatt-hour in this plant, exclusive of investment charges, taxes and insurance, the fuel item amounts substantially to 70 per cent. The calorific value of the fuel used is obviously of the utmost importance, and to insure a supply of coal having a high thermal value is therefore greatly to be desired. This may be accomplished by making use of one of three means which are at our command:

First, to locate the power plant at the mine where good coal lies; second, to bind by contract the supply from certain districts or mines producing coal of known heat value; and third, to purchase coal on a calorific value basis.

The heat efficiency of the power plant referred to in this paper is approximately eight per cent; this means that out of every 100 tons of coal burned, the energy of but eight tons is delivered to the switchboard in the form of electricity. Probably the greatest factor entering into the cost of coal in the United States is the cost of transportation, and as this could be entirely eliminated by locating the power plant at the mine this plan seems attractive. Most unfortunately however, this is impossible as yet, not so much on account of the geographical limitations as of physical conditions. The second plan, which probably is in general use, and no doubt will continue for some time to be employed, was the method by which coal was purchased for this power plant. This plan, however, proved unsuccessful, mainly due to the fact that both good and poor coals exist in the same district or mine, and also because stock coal could be sent in on this contract.

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[1] The author acknowledges with thanks the work of Messrs R. W. Emerson and E. H. Haynes in calculating and experimenting to ascertain the values contained in this paper.

The method of purchasing coal on the basis of calorific value has finally been adopted and with very satisfactory results. Payment is made only according to the B.t.u. contained in the coal, and suitable restrictions are imposed on the maximum amount of ash and sulphur which the coal may contain.

Ohio bituminous slack, of a heat value of 12,500 B.t.u. and with 15 per cent ash and 3.5 per cent sulphur per pound of dry coal, has been specified in the contract because of its relatively low cost, although, at the time when this contract was drawn up it was necessary to take into consideration local conditions to such an extent that the table was made flexible enough to make it possible to supply coal from other districts on the same table. It may be interesting to note that while the purchasing of fuel on a calorific value basis has been attended with good results, it was prompted by a different cause than that which brought about this practice in New York City. There, the predominating influence which effected its introduction, as writer understands, was to restrict the volatile matter the contained in the coal, on account of the stringent smoke regulations.

Here, upon the threshold of two great coal-producing districts, with a difference in freight rate from them to this city and with a considerable difference in price between the coal from each district, it occurred to the writer that some severe restrictions must be placed upon the quality of coal sent in. The city of Cleveland has in effect a heat-value contract under which is purchased the slack required by the Water Department. The heat value of the coal is placed rather high and the coal is required to be up to or above this standard when the contract price is paid. But for coal running less in heat value than that called for by the contract, a deduction in price is made in proportion to the amount less than the standard. Aside from this, however, no information was at hand or available, as far as the writer knows, covering the purchase of slack on a heat-value basis. The case of the Interborough Rapid Transit

Company of New York and several others within the writer's knowledge covered a very high grade of fuel, and, therefore, a good many allowances had to be made in the nature of restrictions which should be imposed upon the amount of fixed carbon, volatile matter and moisture contained in the coal. In lieu of this the company abandoned the idea of placing a premium upon a certain minimum of ash in the coal.

Early experience with the grade of fuel to be supplied under the heat-value contract has shown that coal which runs high in heat value is usually low in ash, sulphur, and moisture, so it became only necessary to limit the coal to the maximum permissible amount of ash and sulphur; subsequent experience has confirmed this hypothesis.

A point worthy of being mentioned here is that the standard in the contract has been made rather low. This was done in order to get a low basic contract price, for when it is understood that premiums and penalties are of an accelerating rate on either side of the standard, and based on the contract price, it may be better understood. As a matter of fact it was expected to pay slightly more than the prevailing contract price of slack as a guaranty of good coal, and in the light of the contrast with the quality of coal received under the old contract in force prior to the inauguration of the purchase of coal on the heat-value basis, this policy has been justified.

Another point of interest, and one which has a very marked influence on the success or failure of this kind of contract, is the personality of the coal dealer. Only the most responsible parties should be dealt with.

There are available in the Cleveland market in extensive quantities two principal grades of bituminous slack, one coming from the Western section of Pennsylvania, the best of which is known as Youghiogheny gas slack, and the other from the Eastern part of Ohio.

For a period of about two months before the contract was put into effect, the company made a series of evaporative tests to determine the relative steam making qualities of Ohio bituminous slack and Youghiogheny gas slack. These tests clearly indicated that in the furnaces as constructed, and with the draft available, both Youghiogheny slack and Ohio slack can be burned with equally good results. Average chemical properties of the two kinds of slack, per pound of dry coal, are as follows:

	Youghiogheny Gas slack.	Ohio Bituminous slack.
B.t.u.	13,185	12,614
Ash	11.6%	13.8%
Sulphur	2.03%	3.53%
Volatile combustible matter	31.95%	36.62%
Fixed carbon	53.52%	45.55%

The relative evaporation per pound of coal as fired was 7 per cent in favor of the Youghiogheny gas slack. The inherent moisture contained in the coal in the first case is 1.52 per cent and in the second case 2.7 per cent.

Basis upon which payments are to be made. In order to illustrate the work of sampling shipments of coal received, and to describe how adjustments of any disputes which may arise between the contracting parties are made, the section of the contract relating to these matters is herewith reproduced. This general method was devised and put into effect by the Interborough Rapid Transit Company of New York, a few years ago, and the essential features, modified to suit local conditions, have been adopted by the traction company.

Each day's consignment of coal furnished to each power plant by the contractor during the continuation of the contract, is sampled by the superintendent or his authorized agent and analyzed to determine its heat value, and the price paid by the company, per ton, for each car of coal is based on a table of heat values in excess or deficiency of the standard therein contained, but subject to further deductions for ash and sulphur.

A small quantity of coal is taken from at least five different places in each car received, by driving into the coal a five-foot ram (Fig. 1), before the car is unloaded. The quantities thus received from each car of coal of the day's consignment are thrown into a receptacle provided for this purpose, and thoroughly mixed, and a properly selected sample of this mixture is taken for chemical analysis. One-half of the sample of the average mixture is labeled and held at the company's laboratory for a period of two weeks after unloading the cars. The other half of the sample taken from the average mixture is analyzed as soon as possible after being taken. No other sample is recognized.

Tests of the sample taken from the average mixture are made by the company's chemist under the supervision of the superintendent. Should the contractor question the results of the company's test, a copy of which is mailed to him, the company will, if requested within three days after the copy of test has been mailed, forward the other half of the sample, held for this purpose, to any laboratory in the city of Cleveland which may be agreed upon by the superintendent and the contractor, and have the said sample analyzed by it, and the results obtained from this second test shall be considered as conclusive and final. In case the disputed values, as obtained in the company's test, shall be found by the second test to be two per cent or less in error, then the cost of the second test shall be borne by the contractor; but if the disputed values shall be found to be more than two per cent in error then the cost of the second test is to be borne by the company.

Should there be no question raised by the contractor within the three days specified, as to the accuracy of the company's analysis, the second sample of coal is destroyed at the end of two weeks from the date of unloading the cars from which it was taken. Should a second test be made of the sample of the average mixture, as provided, then any penalties to be made will be based on the results as obtained from the second test.

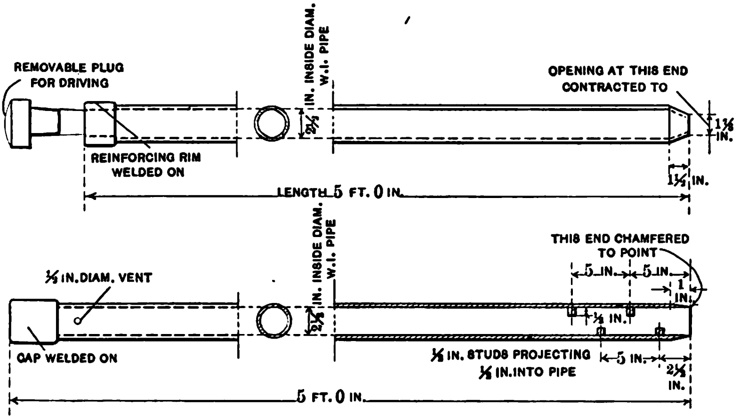
REMOVABLE PLUG FOR DRIVING
2½ IN. INSIDE DIAM. W.I. PIPE
OPENING AT THIS END CONTRACTED TO
1⅛ IN.
REINFORCING RIM WELDED ON
1½ IN.
LENGTH 5 FT. 0 IN.
2½ IN. INSIDE DIAM. W.I. PIPE
THIS END CHAMFERED TO POINT
5 IN.
5 IN.
1 IN.
⅛ IN. DIAM. VENT
CAP WELDED ON
½ IN.
⅛ IN. STUDS PROJECTING ⅛ IN. INTO PIPE
5 IN.
2½ IN.
5 FT. 0 IN.

FIG. 1—Slack sampling rams at the Viaduct and Cedar avenue power stations

Penalties for excess ash and sulphur. Coal which is shown by analysis to contain less than 15 per cent of ash and 3.5 per cent of sulphur is accepted without a deduction on that account. Where the analysis gives amounts of any neutral elements in excess of these quantities, deductions are made from the basic contract price in accordance with a schedule provided, independent of the corrections made for departures from the standard B.t.u. value.

It will be noticed that each day's consignment of coal delivered to each power plant is analyzed, instead of each individual carload of coal, although a sample is taken from each car. The object of this plan is to obtain an average of the whole day's supply in order to allow the dealer the benefit of cars of coal running low in ash and sulphur offsetting those running high.

PREMIUMS AND PENALTIES.

For coal in any car wihch is found by analysis to contain per pound of dry coal

13,975 and above	35 cents per ton above standard
13,850 to 13,974, inclusive—	35 " " " " "
13,725 " 13,849 "	30 " " " " "
13,600 " 13,724 "	25 " " " " "
13,475 " 13,599 "	21 " " " " "
13,350 " 13,474 "	17 " " " " "
13,225 " 13,349 "	13 " " " " "
13,100 " 13,224 "	10 " " " " "
12,975 " 13,099 "	7 " " " " "
12,850 " 12,974 "	5 " " " " "
12,725 " 12,849 "	3 " " " " "
12,600 " 12,724 "	1.5 " " " " "
12,475 " 12,599 "	Standard
12,350 " 12,474 "	1.5 " " " below "
12,225 " 12,349 "	3 " " " " "
12,100 " 12,224 "	5 " " " " "
11,975 " 12,099 "	7 " " " " "
11,850 " 11,974 "	10 " " " " "
11,725 " 11,849 "	13 " " " " "
11,600 " 11,724 "	17 " " " " "
11,475 " 11,599 "	21 " " " " "
11,350 " 11,474 "	25 " " " " "
11,225 " 11,349 "	30 " " " " "
11,100 " 11,224 "	35 " " " " "
10,975 " 11,099 "	40 " " " " "
10,874 " 10,874 "	45 " " " " "
10,725 " 10,849 "	50 " " " " "
10,600 " 10,724 "	55 " " " " "
10,475 " 10,599 "	60 " " " " "
10,350 " 10,474 "	65 " " " " "
10,225 " 10,349 "	70 " " " " "
10,100 " 10,224 "	75 " " " " "
9,975 " 10,099 "	80 " " " " "

9,975 and below an additional 10 cents per ton, per car will be deducted for each one per cent variation below standard.

The plan also offers the advantage to the company that, on account of having a fewer number of samples to analyze, the chemist is not hurried in his work and can therefore devote more attention to the preparation of samples and to the checking of his determinations.

The table of allowances referred to in this section of the contract is so proportioned as to incite the dealer to supply Ohio bituminous slack of a value ranging from 12,500 B.t.u., the standard in the contract, to 13,125 B.t.u., 5 per cent above the standard; this range gives him the best profit obtainable. In order to guard against the supply of fuel having a high B.t.u. value, but which, by reason of its chemical composition, is not well adapted to the stoker equipment, a limit has been set, above which no further premiums are paid.

DEDUCTIONS ON ASH.

00.0 to 15%, inclusive—	Standard
15.1 “ 16 “	3 cents below standard, per ton
16.1 “ 17 “	6 “ “ “ “ “
17.1 “ 18 “	9 “ “ “ “ “
18.1 “ 19 “	12 “ “ “ “ “
19.1 “ 20 “	15.5 “ “ “ “ “
20.1 “ 21 “	19 “ “ “ “ “
21.1 “ 22 “	22 “ “ “ “ “
22.1 “ 23 “	25 “ “ “ “ “
23.1 “ 24 “	28 “ “ “ “ “
24.1 “ 25 “	31 “ “ “ “ “
25.1 “ 26 “	34 “ “ “ “ “
26.1 “ 27 “	37 “ “ “ “ “
27.1 “ 28 “	40 “ “ “ “ “
28.1 “ 29 “	43 “ “ “ “ “
29.1 “ 30 “	46.5 “ “ “ “ “

DEDUCTIONS ON SULPHUR.

0.0 to 3.9%, inclusive—	Standard
4.0 “ 4.4 “	2 cents per ton below standard
4.5 “ 4.9 “	5 “ “ “ “ “
5.0 “ 5.4 “	7 “ “ “ “ “
5.5 “ 5.9 “	9 “ “ “ “ “
6.0 “ 6.4 “	12 “ “ “ “ “
6.5 “ 6.9 “	14 “ “ “ “ “
7.0 “ 7.4 “	16 “ “ “ “ “
7.5 “ 7.9 “	19 “ “ “ “ “
8.0 “ 8.4 “	21 “ “ “ “ “
8.5 “ 8.9 “	23 “ “ “ “ “
9.0 “ 9.4 “	26 “ “ “ “ “
9.5 “ 9.9 “	28 “ “ “ “ “
10.0 “ 10.4 “	30 “ “ “ “ “

To guard against a supply of low-grade cheap coal or slack which has been kept in stock, the B.t.u. value table is so arranged that the value can fall but 10 per cent below standard, where by reason of the addition of penalties due to ash and sulphur on this sort of fuel, the price is cut to such an extent that only the freight charges are realized.

Almost immediately after the contract went into effect, a marked improvement in the cost efficiency of the entire plant took place, accompanied by an improvement of some eight per cent in the consumption of coal per kilowatt hour.

In conclusion it may be said that the installation of the scheme of purchasing fuel on a heat-value basis has been justified.

Taking samples. In the preceding paragraphs reference has been made to a ram by means of which samples are taken from the car. The efficiency of the ram when used for this purpose is indicated by the table below.

	Sample taken by hand at regular intervals while car was being unloaded.	Sample taken from top of car.	Sample taken by means of ram.
Wt. of sample......	600 lbs.	20 lbs.	20 lbs.
B.t.u...............	12,843	12,918	12,777
Ash...............	10.96%	10.4%	11.3%
Sulphur............	2.51%	2.53%	2.56%

A sample obtained in instalments during unloading, taken with great care and diligence, may be said to be truly representative of the entire contents contained in the car. It was, however, soon found to be unsatisfactory in practice as the men, when unloading cars, unless closely watched, would take enough coal at once, in order to get through with the job as soon as possible.

The sample obtained by ram is shown to be very satisfactory, and owing to the fact that the human element involved is cut to a minimum, fairly accurate samples can be easily and quickly secured right after the cars are placed by the railroad company.

Description of analytic work in laboratory. After the coal in the cars has been sampled and ground up into coarse particles, it is brought to the laboratory for analysis. About 2 pounds of the sample from each car are thoroughly mixed together with a large spatula, in order to obtain a fair average of the whole day's shipment. Slack coal and run-of-mine are not mixed, however, but treated as separate samples. The mixed coal is now quartered down until about 0.5 pound of the original amount is left. This part is again mixed, spread out in a thin layer and about 20 to 25 grams of it removed from various points with a small spatula, to be used as the sample for analysis. The remainder is put away in an air-tight sample can, properly labeled for future reference. The smaller part is ground repeatedly with a muller and bucking board until the whole will pass through a 100-mesh sieve. The pulverizing and sifting thoroughly mixes the sample, which is put into the heater for one hour at a temperature of 100 degrees cent. The heater consists of a copper oven surrounded by a water jacket, in which the water is kept at a boiling temperature by a bunsen burner. The coal, now dried out, is ready for analysis. Sulphur, ash and British thermal units are the constituents usually determined—although moisture and volatile combustible matter are sometimes required for boiler and stoker tests.

Sulphur determination. For the sulphur, 0.5 gram of the dry sample is weighed. Two determinations are carried on simultaneously on each sample, in order to have a check on the results. The 0.5 gram of coal is put into a 20-gram platinum crucible half-filled with Eschka mixture, then stirred together, covered with a little more of the mixture and placed over a bunsen flame turned very low, for fifteen minutes. Eschka mixture consists of two parts (by weight) of calcined magnesium oxide, (MgO) and one part (by weight) of dried sodium carbonate, (Na_2CO_3). At the end of 15 min. the flame is gradually turned up to full power, and the mixture heated for 45 minutes, meanwhile being stirred several times. After the whole has been fused and the coal completely burnt out, the contents are turned into a clean beaker, that part of the fusion adhering to the crucible being washed out by means of distilled water and a rubber-tipped stirring rod. 50 c.c. of distilled water are added to the beaker, the whole allowed to boil for a minute on the hot plate, then filtered through a single filter (Munktell 9 c.m.), the precipitate washed with distilled water, 15 c.c. of 1 to 1 hydrochloric acid (HCl) of specific gram, 1.19 added to the filtrate, the solution boiled for a minute and stirred, then 10 c.c. of saturated barium chloride solution ($Ba\ Cl_2$) added, and the resulting precipitate of barium sulphate ($Ba\ SO_4$) allowed to settle for two hours or longer, while the beaker rests on the hot plate. When settled, the precipitate is filtered off, (using double filter papers), and washed three times with hot distilled water. The filters are then folded around the precipitate, both placed in a clean platinum crucible, and heated over the bunsen flame until burned out. This takes about half an hour. From the weight of precipitate found is subtracted the weight of $Ba\ SO_4$ obtained as the average of two or three blanks previously run on the Eschka mixture. The corrected weight of sulphate is doubled, (as but 0.5 gram of sample was taken), multiplied by 0.1373—the sulphur factor—

and then by 100 to obtain the percentage of sulphur in the coal sample. A sulphur table for half-gram weights is then furnished for reference, thus saving time in figuring results. With six burners and six crucibles at hand, six determinations on three samples of coal are carried on at one time.

Ash determination. When the fused mass in the foregoing sulphur determination has been removed from the crucible, the latter is thoroughly washed out, and in it is placed a gram of the dried coal, accurately weighed for the ash determination. This consists in merely allowing the coal to completely burn out over a full bunsen flame. Sometimes the sample is heated to constant weight, but if burned for two or three hours with frequent and careful stirring, the extra weighing is unnecessary. From the weight of residue found, the percentage of ash in the sample is calculated in the usual way. A half-gram of sample may be used instead of the whole gram, though any error is doubled in this way. Two determinations are made at a time on one sample, and they should check within 0.2 per cent.

While the samples are being heated in the crucibles for sulphur and ash, the B. t. u. determinations are made.

British thermal unit determination. This is accomplished with a Parr calorimeter, which measures the rise in temperature of 2 liters of distilled water, due to the heat absorbed from the combustion of a fixed amount of coal sample with an oxydizing agent. This combustion takes place in a metal bomb, which is immersed in the water, and caused to rotate about 100 rev. per min. by a small motor. The coal and oxydizing agent are made to combine by passing a current from a 40-ampere-hour storage battery, giving 6 volts, through an electric fuse in the bomb mixture. The fuse wire is of german silver, No. 36, which melts on passage of the current, and starts combustion of the coal. The water used in the calorimeter for the heat absorption is protected from outside heat influences by two fibre tubs with air spaces between.

To determine the heat units in a sample of coal, the bomb is first taken apart, all the parts washed and thoroughly dried, and the fuse wire fastened to the inside terminals in the form of a loop. 0.5 gram of potassium chlorate ($K\,Cl\,O_3$) and 0.5 gram of coal sample are weighed and placed in the bomb. To this is added a measure (10 grams) of dry sodium peroxide ($Na_2\,O_2$). The bomb is now put together, screwed tight with a wrench, well shaken, the water veins adjusted, then immersed in the 2 liters of water, and made to rotate slowly to secure uniform temperature by the circulation of the water. After about three minutes, the temperature of the water is read from a Fahrenheit scale thermometer inserted through the cover of the calorimeter. The thermometer is calibrated in twentieths of degrees, but the readings are estimated, with the aid of a magnifying glass, to hundredths. After the mercury column has become stationary, the charge in the bomb is exploded, and the thermometer carefully watched, as the mercury rises, until the maximum temperature is reached. The difference between the first reading of the thermometer and the last reading is the rise due to the heat absorbed by the water.

A rise of 0.014 degrees fahr. is due to the heat of the fuse wire used, and a further rise of 0.171 degrees fahr. is caused by the accelerator ($K\,Cl\,O_3$). The sum of these two (0.185) is subtracted from the total rise in degrees, and the remainder is multipled by 3117 to obtain the number of heat units in the sample.

The number of heat units is the number of grams or pounds of water that 1 gram or 1 lb., respectively, of coal sample during combustion, will cause to rise 1 degree fahr. in temperature.

The above factor, 3117, is obtained in this way: the 2000 c.c. of distilled water used in the calorimeter weighs 2000 grams; the metal bomb and metal-containing cylinder and pivot together are the equivalent of 135 grams of water on the basis of heat absorption. 2000 grams plus 135 grams gives 2135 grams. This number multiplied by the rise in degrees would give the number of gram calories in fahr. degrees given off when 0.5 gram of coal was burned. Therefore, twice this amount represents the calories of heat from 1 gram of coal. It has been experimentally determined that when coal, $K\,Cl\,O_3$, and $Na_2\,O_2$ are exploded, only 73 per cent of the heat evolved is due to the combustion of the coal. $2135 \times 2 \times 0.73 = 3117$ which represents the number of gram calories due to a rise of 1 degree.

After each explosion, the bomb is washed out, dried, and wired for the next charge. The 2 liters of water used should be about 4 degrees lower than the temperature of the room, and fresh distilled water is used for each explosion. Two determinations for heat units are always made on each sample, and should agree closely. If the rise in temperature in one case varies more than 0.02 of a degree with the rise on another explosion of the same sample, (corresponding with 62 heat units) then successive determinations are made on this coal until a check or a good average is obtained. A calorific table does away with the calculation and results are obtained directly.

Moisture determination. To find the moisture content the coal in question is first air-dried, a gram of it weighed, placed in the heater at 104 degrees cent. for one hour and weighed again. The loss in weight divided by the weight of air-dried coal gives the percentage of moisture.

Volatile combustible matter determination. For the percentage of volatile combustible matter in coal, a 1 gram sample is placed in a clean weighed platinum crucible, the cover put on tightly, and the coal heated over the strongest heat of a bunsen burner for three and one-half minutes. At the end of this time the bunsen flame is removed and a blast lamp put under the crucible, taking care to have a flame below the crucible while making the change, so the contents will not cool. The coal is heated by the blast lamp for three and one-half minutes more, the crucible allowed to cool in a desiccator and weighed. From the loss in weight from heating, the weight of moisture found is subtracted, and the difference divided by weight of the sample taken to find the percentage of volatile combustible matter. This difference also contains one-half the sulphur, and this value, found in another determination, is subtracted leaving the per cent of volatile combustible matter.

Fixed carbon determination. Remove the cover and burn off the remaining carbon over a bunsen burner until nothing remains but the ash—the loss is fixed carbon with the remainder of the sulphur.

Coke and ashes are analyzed in much the same way that coal is, except that tests for sulphur and moisture are not required. In determining the heat units, however, it is difficult to get an explosion with the ordinary chemical, so the use of benzoic acid is resorted to. 0.5 gram of $KClO_3$, 0.25 gram of coke or ash sample, 0.25 gram of benzoic acid (C_6H_5COOH), and 10 grams of Na_2O_2 are used fo each charge. A correction must be made not only for the wire and accelerator, but also for the benzoic acid. This correction is found by running two or three blanks of 0.25 gram $KClO_3$, 0.25 gram acid and 10 grams Na_2O_2 for each lot of chemicals and taking the average. From the total rise in degrees after the explosion of coke or ash sample, the blank correction is first subtracted, and the remainder multipled by 6234 (2×3117, as but 0.25 gram of sample instead of 0.50 gram was used) to obtain the number of heat units. For the determination of ash in coke or ashes, but 0.50 gram is taken, as the combustion is slower with these substances.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

REPORT OF THE BOARD OF DIRECTORS FOR THE FISCAL YEAR ENDING APRIL 30, 1909.

The Board of Directors presents herewith for the information of the membership its annual report, including brief references to the work of the various standing and special committees; also the usual statements showing the financial standing of the organization.

The Annual Convention was held at Atlantic City, June 29–July 2, 1908. The total registered attendance was 469. Thirty-five professional papers, including the President's annual address, were presented and discussed.

The Board of Directors has held 10 regular monthly meetings during the year.

On recommendation of the Finance Committee the Board directed the investment of certain Institute funds, during the year, as follows:

On June 1, 1908, of the cash surplus on deposit, drawing interest at the rate of 3%, there was invested in New York City 4½% bonds of 1957, par value $1,000 each, $10,950. On September 17, 1908, there was effected an exchange of eight $1,000 U. S. Government 3% bonds, value $8,107.50, for eight $1,000 New York City 4½% of 1917, purchase price $8,502.25. The difference in the respective values of the bonds, $394.75, was paid from the cash-surplus on deposit. On October 13, 1908, there was drawn from the International Electrical Congress Fund, the total amount of which was $2,333.07, drawing interest at the rate of 3%, the amount of $2,268, which amount was invested in two $1,000 New York City 4½% bonds of 1957, leaving a balance on deposit, in the International Electrical Congress Fund, of $65.07.

During the year the Institute By-laws were revised by a special committee of the Board of Directors, and were adopted by the Board on November 13, 1908, as revised by the committee, going into effect immediately.

Building Fund Committee.—The amount collected from subscribers during the year was $7,719.40. The interest on the bank balances amounted to $383.36. In addition to these amounts, $9,221.95 was refunded to the Building Fund for payments of interest on the mortgage during the period of occupancy of the building 25-33 West Thirty-ninth Street. These items make a total to the credit of the Building Fund during the year, of $17,324.71. (See financial statements at end of this report.)

Board of Examiners.—The Board held nine meetings during the year, and considered applications for election as Associates, enrolment as Students, and transfer to the grade of Member, which were reported to the Board of Directors, as follows:

Recommended for election as Associates	916
Recommended for enrolment as Students	687
Recommended for transfer to the grade of Member	45
Not recommended for election as Associates	2
Not recommended for transfer to the grade of Member	20
Total number of cases considered	1,670

In accordance with the Constitution, Local Representatives of the Board of Examiners were appointed last fall, in various cities of the United States, Canada, and Mexico, to assist the Board in procuring information regarding applicants in their respective territories.

Sections Committee.—The reports of the secretaries of the Sections and Branches show a marked increase in the activity of the local organizations during the year. There are now 23 active Sections. A year ago there were 22 Sections, two of which, however, were inactive. Three new Sections were organized during the year, as follows:

Fort Wayne, Ind., authorized August 14, 1908.
Los Angeles, Cal., authorized May 19, 1908.
Madison, Wis., authorized January 8, 1909.

The Madison Section was formerly the University of Wisconsin Branch, and its change to a Section indicates increased interest in the local organization. In addition to the Section authorized, several meetings of local members have been held at Portland, Oregon and a petition from the Portland members for authority to organize a section has been received and will probably be acted upon at the May meeting of the Board of Directors.

There are 27 Branches, two of which were organized during the year, as follows: Case School, Cleveland, O., authorized January 8, 1909, and New Hampshire College, Durham, N. H., authorized February 19, 1909.

The increased activity of the Sections and Branches is indicated by the following brief summary made up from the reports received at the Secretary's office.

Sections.

	May 1, 1907 to April 30, 1908	May 1, 1908 to March 31, 1909	Increase over last year
Section meetings held	141	169	28
Original papers presented	120	167	47
Institute papers "	38	24	
Attendance	7,476	16,427	8,951

Branches.

Branch meetings held	143	198	55
Original papers presented	84	158	74
Institute papers "	66	52	
Attendance	4,128	8,443	4 315

It will be noted from the above summary that the figures for 1908–1909 cover a period of only 11 months. This large increase is due in some measure to the coöperation of the local secretaries with the Institute office in sending in reports regularly, but more particularly to greater local interest and activity.

Standards Committee.—A meeting of this committee was held at Institute headquarters on December 10, 1908. It was decided to attempt no revision of the Standardization Rules during the present year. At the request of the U. S. National Committee of the International Electrotechnical Commission, certain questions on international nomenclature were considered.

International Electrotechnical Commission.—The U. S. National Committee of the International Electrotechnical Commission held a meeting on June 30, 1908, at Atlantic City on the occasion of the A.I.E.E. Convention.

A communication dated July 15, 1908, was received from the French committee, at the instance of the Bureau of Standards, proposing an international candle. The endorsement of this proposal was obtained from the members of the present U. S. committee and reported to the General Secretary in London, on September 25, 1908. The council meeting of the commission was held in London, on October 19, 1908. At this meeting Professor Elihu Thomson was unanimously elected President of the commission, to succeed the late Lord Kelvin. Certain modifications were adopted in the rules of the commission. It was voted that the commission should undertake to prepare a glossary of important international terms. The proposal of the French committee in regard to an international candle was laid over for consideration by the national committees. It was agreed that in future all measurements used by the commission should be expressed in terms of the metric system, with equivalents in parentheses when desired. A proposal has been received from the British committee to adopt an international candle = 10/9 of a hefner = 0.104 carcel = 1 bougie decimale = 1 pentane candle. This would place the American, British and French candles on a parity, to be maintained by the national standardizing laboratories of those countries. It involves a reduction of 1.6% of the unit of candle-power heretofore maintained by the Bureau of Standards. The proposal has been endorsed by the Bureau of Standards and all of the members of the U. S. committee. The 1.6% change in candle-power has been approved by the American Institute of Electrical Engineers, the American Gas Institute, and the Illuminating Engineering Society. National committees of the commission now exist, in addition to the United States; in Canada, Mexico, Great Britain, Germany, France, Hungary, Belgium, Italy, Spain, Sweden, Denmark and Brazil.

Library Committee.—The complete report of this committee will be printed in the Institute PROCEEDINGS in the near future.

Committee on Intermediate Grade of Membership.—The committee has considered along broad lines the question of the need and practicability of adding one or more grades of membership to those now existing. It has examined the classification of other organizations having various grades of membership. The subject has proved an extremely difficult one, involving, as it does, general policy, as well as a large amount of detail. The committee is now formulating its views in regard to the various points involved, and will probably suggest that its report be printed in the PROCEEDINGS, and the views of the membership in regard to the subject be invited.

Committee on Bibliography.—This committee has completed its work upon the catalogue of the Wheeler Gift of Books, Pamphlets and Periodicals. The catalogue has been published in two volumes and is now being distributed.

Meetings and Papers Committee.—During the past year this committee arranged for eight regular and two special meetings. Nine papers were presented at the eight regular meetings. One of the special meetings was devoted to the subject of conservation of natural resources, and the other to industrial education. The efforts of the committee, throughout the year, have been directed towards securing a single paper of unusual merit for each regular meeting. The subjects were selected so as to cover as fully as possible the broad field of electrical engineering, in order to appeal to the diversified membership. The several sub-committees of the Meetings and Papers Committee have been utilized during the year to supply papers and discussions on their special subjects, with gratifying results.

Educational Committee.—The committee held two meetings during the winter, in New York City, at which the scope of the work was discussed and plans were made for two special meetings of the Institute. At the outset it was decided that as technical education had been treated exclusively during the preceding year, industrial training should be adopted, as the topic for the current year. As a part of this plan a special meeting of the Institute was held in New York, under the auspices of the committee, on April 16, 1909. As a further part of the plan, a special session of the 1909 Convention will be occupied with papers and discussions on the general subject of industrial education. In addition to the preparations for the meetings mentioned, the committee has carefully considered a plan for holding examinations throughout the country, under the auspices of the Institute. The committee has also considered a plan for assisting in research work throughout the country, by compiling lists of suitable subjects for investigation.

High-Tension Transmission Committee.—The Institute has held one meeting under the auspices of this committee, on April 9, 1909. Two papers were presented and discussed at this meeting, and there were conducted on the stage of the auditorium some tests of terminals at voltages up to 250,000. It is contemplated that at least one session at the annual convention will be under the auspices of this committee.

Committee on Industrial Power.—A number of meetings of this committee have been held during the year. Nearly all of the Sections have held meetings devoted to the subject of industrial power, as a result of the efforts of the committee. It was hoped that the papers presented at these meetings could be collected and published in book form, but it was found impossible. It may be possible, however, to do this next year. The regular March meeting of the Institute was devoted to the subject of industrial power. It is planned to devote one of the sessions of the annual convention to this subject.

Editing Committee.—Since September, 1908, there have been edited and published eight numbers of the PROCEEDINGS. The total number of pages of these PROCEEDINGS is 1701; of this total, 304 pages have appeared in Section I; 767 pages in Section II. Of the 767 pages in Section II, 354 pages were devoted to technical papers and 413 pages to discussions.

Vol. XXVII, of the TRANSACTIONS, consisting of the papers, and discussions during the calendar year 1908, the report of the Board of Directors for the fiscal year ending April 30, 1908, and the By-Laws, contains 1716 pages. Vol. XXVII will be issued in two parts. Part I, consisting of 858 pages, will contain the papers and discussions presented between January 1, 1908, and the end of the morning session on June 30, 1908, at the Annual Convention at Atlantic City, the report of the Board of Directors, and the By-Laws. Part II, also consisting of 858 pages, will contain the papers and discussions presented between the evening session on June 30, 1908, at the Atlantic City Convention, and December 31, 1908. The volume will probably be ready for distribution about August 1, 1909.

The chairman of the Editing Committee has given personal attention to all the MSS., of the papers and discussions at the Institute Sections and Branches that have been forwarded to the Secretary's office during the present administration. Thirty-six MSS., of this nature have been received and passed upon. These MSS., consisted of approximately 700 pages of typewritten matter.

Law Committee.—The Law Committee considered and reported upon various questions submitted to it by the Board of Directors during the past year, the most important matter being the advisability of drafting by-laws to govern the actions of the Meetings and Papers, and Editing committees. After careful consideration of the subject it was the unanimous opinion of the committee that the conditions governing the acceptance of papers and discussions were so varied as to make it impossible to draft any rigid rules for the guidance of those committees, and that the present right of appeal to the Board of Directors, which any member now has, was a sufficient safeguard of the rights of all members.

Code Committee.—The Code Committee has held a number of meetings during the year. The most important matter that has been considered was in connection with Rule 13-A of the Board of Fire Underwriters. This rule deals with the grounding of secondary circuits. The committee agreed that the rule should be made mandatory up to and including 150 volts between any wire and ground, and optional up to and including 250 volts between any wire and ground. This resolution was handed to the president of the National Conference on Electrical Rules. Final action on the resolution was deferred, pending an arrangement for a meeting of the Code Committee with a committee of the National Board of Fire Underwriters.

Committee on Conservation of Natural Resources.—During the past year the Committee on Natural Resources has carried on correspondence and held informal conferences with representatives of the U. S. Government and with other societies, looking to the furtherance of the legitimate object of the conservation movement. The committee also originated the movement which resulted in a very successful joint meeting held March 24, 1909, under the auspices of the four national engineering societies. The committee feels that two extremely valuable objects were gained in this joint meeting: 1. The presentation of the engineers' views on the conservation movement. 2. Bringing the four societies to act jointly on this subject, which establishes a precedent for similar action on other important subjects of common interest to all, and has a tendency to promote cordial relations between the societies.

Edison Medal Committee.—Before the new deed, entitled " Amended and Substitute Deed of Gift Creating the Edison Medal ", was executed, on March 26, 1908, five graduate students from institutions of learning, duly qualified to compete for the Edison Medal under the old deed, had submitted theses in competition for the medal for 1907. These students, at the request of the Institute, withdrew from competition for the medal, and resubmitted their theses in a special competition for a Diploma of Merit, plus a cash award of $150.00. A sub-committee of the Edison Medal Committee reported to the chairman on May 8, 1909, its recommendation in respect to the award on the student theses, which will be acted upon at a meeting of the Edison Medal Committee on May 18.

Revision of the by-laws of the Edison Medal Committee was begun in October, 1908, and a final draft as approved by the committee was presented to the Board of Directors on December 11, 1908.

John Fritz Medal.—The John Fritz Medal Board of Award upon which the Institute is represented arranged for a meeting which was held on April 13 at which the medal for 1909 was presented to Mr. Charles T. Porter, for meritorious service in the advancement of steam engineering. Four addresses were made at this meeting by representatives of the four national engineering societies.

Increase of Membership Committee.—This committee has held several meetings during the year, and has sent out numerous letters and circulars. A special effort was made to interest engineers in the U. S. Army and Navy. During the year ending May 1, 1909, 1079 applications for membership were received—almost as many as were received during each of the two preceding years.

Membership. The present total membership and the increase during the past year are indicated below:

	Hon. Mem.	Mem.	Assoc.	Total
Membership, April 30, 1908	1	573	5,100	5,674
Additions:				
New Associates			1,005	
Transferred		53		
Deductions:				
Died		4	13	
Resigned		4	66	
Dropped		11	181	
Transferred			53	
Membership April 30, 1909	1	607	5,792	6,400

Net increase during the year in membership........................726

Resignations.—The following Members and Associates have resigned **during the year in good standing.**

Members.—F. W. Brady, J. W. Swinburne, C. H. Wilmerding, C. H. Wordingham.

Associates.—J. C. T. Baldwin, R. J. Barker, B. H. Bendheim, E. R. Berry, R. H. Black, A. E. Blondel, C. A. Bramhall, A. U. Brandt, J. Brayshaw, W. S. Brewster, A. J. Brown, W. D. Brown, Leonard Carpenter, M. E. Chester, A. S. Clift, B. W. Cooper, W. R. Cooper, W. W. Dean, B. M. Drake, Edward Durant, C. D. Ehret, Albert Esling, E. E. Ferrin, W. S. Ford, M. J. Francisco, J. B. Edwards, E. E. Gage, H. L. Gilbert, Leon Goldsmith, W. M. Haddock, C. G. Halleck, W. L. Hildburg, Christopher Hoff, Jr., B. K. Hough, James C. Howe, W. McA. Johnson, Henry Kaetker, P. H. Knight, F. N. Koziell, P. J. Kreusi, F. F. Lee, Norman Leeds, C. H. Machen, Benjamin Magnus, B. F. Mechling, Jr., L. G. E. Morse, M. M. Neurath, M. L. Norris, R. B. Parrott, Carroll Potter, J. D. Ross, E. H. Rupe, R. A. Scott, T. G. Seidell, A. B. Skelding, W. W. Sloane, W. Stuart Smith, A. B. Stetson, F. K. P. Stilwell, Julius Strauss, S. Tada, J. C. Van Buren, W. M. Venable, S. T. Wellman, Charles West, J. M. Zapata.

Total resignations, 70.

Deaths.—The following deaths have occurred during the year:

Members.—W. A. Anthony, E. V. Baillard, C. E. Gifford, F. A. C. Perrine.

Associates.—H. C. Buck, A. M. Bullard, W. H. Cordell, Theodore Dimon, E. G. Eberhardt, A. B. Elliott, Otto Holz, J. M. Mahoney, W. S. Scarlett, E. F. Schaefer, Paul von Lehoczky, F. G. Warman, E. L. Zalinski.

Total deaths, 17.

Delinquent.—Dropped as delinquent during the year, 192.

The average receipts and disbursements *per capita* for the past seven years, are shown in the following table:

RECEIPTS AND DISBURSEMENTS PER YEAR PER MEMBER.

During each fiscal year for the past seven years.

Year	1903	1904	1905	1906	1907	1908	1909
Membership, April 30th, each year	2230	3027	3460	3870	4521	5674	6400
RECEIPTS PER MEMBER:							
Entrance Fees	$1.59	$1.65	$0.83	$0.75	$0.90	$1.21	$0.79
Dues	9.01	9.33	9.30	9.47	8.95	9.36	10.19
Transactions, Sales, Advertising	1.79	2.11	1.70	2.15	1.81	1.83	1.68
Badges	.35	.39	.28	.27	.30	.43	.32
Interest	.21	.18	.21	.13	.25	.18	.23
	$12.95	$13.66	$12.32	$12.77	$12.21	$13.01	$13.21
DISBURSEMENTS PER MEMBER:							
Transactions	$4.67	$3.43	$3.77	$3.33	$2.83	$3.51	$3.65
Salaries	2.49	2.50	2.20	2.64	2.53	2.55	1.93
Meeting Expenses, incl. Sections	.87	1.16	.82	.68	.68	.91	.84
Housing	.65	.79	.75	.68	1.33	1.15	.96
Library, incl. Salaries	1.38	1.39	.81	.69	1.37	.51	.39
Postage	.69	.66	.66	.58	.59	.65	.74
Stationery and Miscel. Printing	.96	1.01	.70	.78	.85	.80	.82
General Expenses	.52	.45	.54	.29	.43	.62	.29
Badges	.27	.35	.25	.22	.29	.40	.28
Express	.15	.28	.22	.23	.28	.14	.23
Advertising				.36	.30	.35	.27
Office Fittings					.14	.14	.09
Total	$12.65	$12.02	$10.72	$10.48	$11.62	$11.73	$10.49
Credit Balance per Member	$0.30	$1.64	$1.60	$2.29	.59	1.28	2.72

LAND, BUILDING AND ENDOWMENT FUND.

Receipts.		Disbursements.	
Before appointment of committee	$ 6,100.00	Paid United Engineering Society, acct. of contract	$ 8,000.00
Collected by Committee	143,328.90	Paid United Engineering Society, acct. of mortgage	99,000.00
Interest on balances	5,381.76	Paid United Engineering Society, acct. of interest	19,529.45
Reimbursement by Institute	9,221.95	Expenses of Committee	10,440.73
		Balance in bank, May 1, 1909	27,062.43
Total	$164,032.61	Total	$164,032.61

New York May 18, 1909.

Mr. Louis A. Ferguson,
President American Institute of Electrical Engineers,
No. 33 West Thirty-ninth Street, New York.

Dear Sir: During the past year your Finance Committee has performed its prescribed duties as provided for in the Constitution and By-laws. We respectfully submit herewith the report of the chartered accountants, Messrs. Peirce, Struss & Company, who have audited the books of the Institute for the year.

Your committee, in company with the Secretary and a representative of the chartered accountants, has examined the securities held by the Institute, and finds them to be as stated in the balance sheet.

In preparing the annual statement this year, the chartered accountants have followed previous practice in omitting from the assets and from the liabilities, any accruals of interest, but we recommend that the Board of Directors instruct that in future statements these accruals be entered on both sides of the balance sheet.

Similarly, the item of Office Furniture and Fixtures is this year set up at its present appraised value, such value being determined by a recent re-appraisal. We recommend that the Board of Directors direct the furniture account to be set up at its full cost value, to which shall be added each year the cost of additional furniture which may be purchased from time to time; that as against this amount a reserve liability fund be created, to which shall be added annually a sum equivalent to a suitable per cent of the total furniture account, such reserve fund to be held against possible replacement of furniture and fittings.

You will note the sum of $9,921.95 entered as a reimbursement of the Land, Building and Endowment Fund, which amount is deducted from the year's surplus. In explanation of this item it seems proper to state that by authorization of the Board of Directors, all payments of interest on the unpaid balance of the cost of land since the Institute has occupied its present quarters, have been adjudged a current expense payable from the Institute current income, and inasmuch as certain sums for this purpose had previously been paid out of the Land, Building and Endowment Fund, an equivalent amount with all interest received on same has been restored to that fund, which accounts for the item referred to.

Respectfully submitted,

Calvert Townley,
Chairman Finance Committee.

New York, May 11, 1909.

Mr. Calvert Townley,
Chairman Committee on Finance.

Dear Sir: In accordance with your instructions, we have audited the books and accounts of the American Institute of Electrical Engineers, for the year ended April 30th, 1909.

The results of this examination are presented in four exhibits, attached hereto, as follows:—

Exhibit A. Balance Sheet, April 30th, 1909.

Exhibit B. Receipts and Disbursements for general purposes for year ended April 30, 1909.

Exhibit C. Receipts and Donations for designated purposes, also expenditures for year ended April 30, 1909.

Exhibit D. Condensed Cash Statement.

We beg to present attached hereto our certificate to the aforesaid exhibits.

Yours very truly,
(Signed) Peirce, Struss & Co.
Certified Public Accountants.

New York, May 11, 1909.

Mr. Calvert Townley,
Chairman Committee on Finance.

Dear Sir: Having audited the books and accounts of the American Institute of Electrical Engineers for the year ended April 30, 1909, we hereby certify that the accompanying Balance Sheet is a true exhibit of its financial condition as of April 30, 1909, and that the accompanying statements of Cash Receipts and Disbursements are correct.

(Signed) Peirce, Struss & Co.
Certified Public Accountants.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Balance Sheet, April 30, 1909.

Exhibit A.

Assets.		
Cash:		
Land, Building and Endowment fund.	$27,062.43	
General Library fund	251.51	
Compounded Membership fund......	5,355.57	
*Mailloux fund.....	1,000.00	
		33,669.51
†General cash in bank............	9,198.65	
Secretary's petty cash on hand.....	500.00	
		9,698.65
International Electrical Congress of St. Louis, 1904, Library fund Bonds	2,268.00	
		2,268.00
New York City 4½% Gold Bonds......	30,000,00	
Premium on Bonds.	1,952.50	
		31,952.50
Westinghouse Elec. & Mfg. Co's stock.		50.00
Equity in Societies Building (25 to 33 West 39th Street)	353,346.61	
One-third cost of land (25 to 33 West 39th Street)	180,000.00	
		533,346.61
Library volumes and fixtures..........	26,644.67	
Transactions........	5,480.25	
Office furniture and fixtures..........	5,139.75	
Works of art, paintings, etc.........	2,300.00	
Badges............	495.30	
		40,059.97
Accounts Receivable:		
Members for past dues suspense acct.	11,283.75	
Members for entrance fees.......	265.00	
Miscellaneous.......	478.51	
For advertising.....	1,762.00	
		13,789.26
Total Assets................		$664,834.50

* The Farmers' Loan and Trust Co. deposit account includes 35c. of the Mailloux Fund.

† $65.44 of the Weaver donation.

$124.72 of Int. Elec. Congress of St. Louis Library Fund.

Liabilities and Surplus.		
Funds:		
Land, Building and Endowment Fund	$27,062.43	
General Library Fund............	251.51	
Compounded Membership Fund.....	5,355.57	
Mailloux Fund......	1,000.35	
International Electrical Congress of St. Louis, 1904, Library Fund:		
Principal.........	2,268.00	
Unexpended Income..........	124.72	
Accounts Payable subject to approval by Finance Committee......	4,035.38	
		40,097.96
United Engineering Society (for cost of land)..........		81,000.00
Total liabilities.		$121,097.96
Surplus:		
In cash............	9,573.58	
New York City bonds............	31,952.50	
In property and accounts receivable.	502,210.46	
		543,736.54
Total liabilities and surplus....................		$664,834.50

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

RECEIPTS AND DISBURSEMENTS FOR GENERAL PURPOSES FOR YEAR ENDED APRIL 30, 1909.

EXHIBIT B.

RECEIPTS.		
Entrance Fees	$5,025.00	
Current Dues	54,759.50	
Past Dues	5,726.00	
Advance Dues	290,50	
Students' Dues	3,957.00	
Transfer Fees	480.00	
Badges	2,084.50	
		$72,322.50
Sales, Transactions, etc.	1,787.26	
Subscriptions, Proceedings	1,439.76	
Advertising	7,228.89	
Binding	137,25	
Exchange	28.21	
Library Sales	114.29	
INTEREST:		
Bonds	977.07	
Bank Balances	512.22	
		$12,224.95
Total		$84,547.45

DISBURSEMENTS.		
Stationery and Printing	4,766.10	
Postage	4,706.43	
General Expenses	1,887.79	
Meeting Expenses	1,960.60	
Section Meetings	3,389.54	
Badges	1,824.05	
Salaries	9,964.00	
Bibliography	485.05	
Office Furniture	546.90	
		$29,530.46
PROCEEDINGS—TRANSACTIONS:		
Printing	16,009.84	
Salary	2,400.00	
Engraving	1,261.10	
Volumes	3,294.57	
Electrotyping	1,023.49	
Binding	1,787.07	
Express	1,475.25	
Advertising Commissions	1,714.27	
		$28,965.59
LIBRARY:		
Librarian & Asst's.	$1,250.68	
Cataloguing	199.17	
Desk Attendant	68.01	
Insurance	88.79	
Binding	247.75	
Supplies	51.69	
Subscription	89.25	
Books	397.12	
Typewriter	15.70	
Printing	17.66	
Book plates	24.50	
Miscellaneous	10.27	
		$2,460.59
United Engineering Society Assessments (Rent)		$6,166.68
Total		$67,123.32
Excess receipts over disbursements		17,424.13
		$84,547.45
To Surplus—as above		17,424.13
Reimbursement of Land Building and Endowment Fund		9,221.95
Net to surplus		$8,202.18

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

RECEIPTS AND DONATIONS FOR DESIGNATED PURPOSES, ALSO EXPENDITURES FOR YEAR ENDED APRIL 30, 1909.

EXHIBIT C.

RECEIPTS.	
Land, Building and Endowment fund, Donations, Interest, etc.	$17,324.71
Carnegie (Library) Fund, Interest	88.72
General Library Fund, Interest	7.36
Compounded Membership Fund, Interest	195.57
International Electrical Congress of St. Louis, 1904, Library Fund, on account of Principal	31.10
International Electrical Congress of St. Louis, 1904, Library Fund, on account of interest	108.28
	$17.755.74
Mailloux Fund Interest ($30.00) received after April 30th 1909	
EXPENDITURES.	
Land, Building and Endowment Fund, on account of Interest and Expense	$3,610.59
Carnegie (Library) Fund	3,256.91
Compounded Membership Fund	440.00
Mailloux Fund	17.00
Weaver Donation	9.56
International Electrical Congress of St. Louis, 1904, Library Fund for Bonds	2,268.00
Total Expenditures	9,602.06
Excess of Receipts over Expenditure	8,153.68
	$17,755.74

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

CONDENSED CASH STATEMENT.

EXHIBIT D.

Cash on deposit April 30th 1908	$37,857.05	
Secretary's petty cash, April 30th, 1908	500.00	
	$38,357.05	
Receipts for general purposes, Exhibit " B "	84,547.45	
Receipts for designated purposes, Exhibit " C "	17,755.74	
		$140,660.24
Disbursements for general purposes, Exhibit " B "	67,123.32	
Expenditures for designated purposes, Exhibit " C "	9,602.06	
Expended for New York City 4½% Bonds	11,344.75	
Reimbursement of Land Building and Endowment Fund	9,221.95	
		97,292.08
Balance on hand, April 30th, 1909		43,368.16
On deposit for designated purposes, Exhibit " A "	33,669.51	
On deposit for general purposes, Exhibit " A "	9,198.65	
Secretary's petty cash, Exhibit " A "	500.00	
		$43,368.16

PROPERTY ACQUIRED DURING THE YEAR.

Office Furniture and Fixtures	$546.90
Library Books and Binding	644.87

Respectfully submitted for the Board of Directors.

RALPH W. POPE, *Secretary.*

New York, May 18, 1909.

REPORT OF THE LIBRARY COMMITTEE.

We submit herewith our report for the year ending April 30, 1909, covering the growth and operation of the library and a statement of the present condition of the various library funds, and of the expenditures for the year.

The gifts to the library during the year reach a total of 273 volumes and pamphlets, while the additions by purchase were 335 volumes and by exchange 201 volumes, making a total of 809 accessions. At the time of the last annual report the library has just received some large additions that had not yet been entered on the library records. From these additions 492 volumes and pamphlets have been acquired making the total increase over the report of one year ago 1301 volumes and pamphlets. The total valuation now placed on the library and the increase for the year is shown in the table of library statistics.

The complete list of donors with the number of volumes presented by each is as follows:

DONORS

ADAMS, E. D	6
ALLGEMEINS ELEKTRICITATS GESELLSCHAFT	1
AMERICAN BELL TELEPHONE COMPANY	2
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS	2
AMERICAN STREET RAILWAY ASSOCIATION	8
BOSTON TRANSIT COMMMISSION	4
BUREAU OF RAILWAY NEWS	1
CALDWELL, EDWARD	68
CARBO, L. A	2
CARNEGIE TECHNICAL SCHOOL	1
CENTRAL ELECTRIC COMPANY	1
CHICAGO DEPARTMENT OF PUBLIC WORKS	1
CLARK, MYRON C., PUBLISHING COMPANY	1
CLAYTON, W. B. & CRAIG, J. U	1
CONNECTICUT BOARD OF ELECTRICAL COMMISSIONERS	1
DIXON CRUCIBLE COMPANY	1
ELECTRIC JOURNAL	1
ENGINEERS SOCIETY, UNIVERSITY OF MINNESOTA	1
FOSTER, H. A	2
FRENCH, MRS. E. D	1
GAS ENGINE	2
GENERAL ELECTRIC COMPANY	1
HERING, CARL	1
INTERNATIONAL ASSOCIATION OF MUNICIPAL ELECTRICIANS	1
IOWA ENGINEERING SOCIETY	3
IRON AGE	1
KANSAS GAS ASSOCIATION	1

McGRAW PUBLISHING COMPANY	56
MACMILLAN COMPANY	2
MAILLOUX, C. O.	25
MARTIN, T. C	7
MASSACHUSETTS GAS COMMISSION	1
MASSACHUSETTS GAS & ELECTRIC LIGHT ASSOCIATION	1
MICHIGAN ELECTRICAL ASSOCIATION	5
MUNICIPAL OWNERSHIP PUBLISHING COMPANY	1
NEW JERSEY COMMISSIONER OF PUBLIC ROADS	1
NEW YORK COMMISSIONER OF ACCOUNTS	1
NEW YORK STATE COMMISSION OF GAS & ELECTRICITY	1
NEW YORK STATE LIBRARY	1
NEW YORK STATE PUBLIC SERVICE COMMISSION, FIRST DISTRICT	1
NEW YORK STATE PUBLIC SERVICE COMMISSION, SECOND DISTRICT	4
NEW YORK STREET RAILROAD ASSOCIATION	1
NEW YORK STATE WATER SUPPLY COMMISSION	1
NEW YORK UNIVERSITY (SENATE)	1
OHIO ELECTRIC LIGHT ASSOCIATION	1
PENNSYLVANIA STATE BOARD OF AGRICULTURE	1
PERTIG, W	1
POOLE, C. E	1
ROEBLING'S SONS COMPANY	1
ROSENTHAL, L. U	1
SNOW, W. B	5
SPRINGER, J	1
STONE & WEBSTER	6
THOMPSON, S. P	2
TORONTO, (CITY ENGINEER)	1
UNDERWRITERS LABORATORY	1
UNIVERSITY OF WASHINGTON	1
VAIL, T. N	1
VAN NOSTRAND COMPANY	10
WEAVER, W. D	1
WESTERN SOCIETY OF ENGINEERS	1
WILEY, JOHN & SONS	1
DONORS UNKNOWN	9
Other Accessions:	
Purchases	335
Exchanges	201
Back Accessions	492
Total Accessions	1301

During the year a reorganization of the library staff and the general administration of the library has been effected. At a meeting of the Trustees of the United Engineering Society held on June 4, 1908, the following plan for the administration of the library was recommended to the governing bodies of the three founder societies:

First: That the administration of the library be placed in the hands of a chief librarian, all employes in the library to be subject to the direction of said chief librarian. It was agreed that Miss L. E. Howard should be appointed chief librarian, her present yearly compensation to be increased $200 in this connection.

Second: That each new employe in the library shall be approved both by the authorized representative of the founder societies interested, and by the chief librarian.

Third: In the event of any employe not being satisfactory to said representative of the founder society interested, or to the chief librarian, the fact shall be reported by the chief librarian to the House Committee, which shall have the power to act.

Fourth: That in the absence of the chief librarian the House Committee shall have the right to specify an employe of the library to act as chief librarian during such period of absence.

Fifth: That the United Engineering Society be requested to pay the salaries of all the library employes, and the amount to be repaid by the founder societies respectively shall be distributed in such proportion as may be jointly agreed upon.

At the meeting of the Institute Directors held on Friday June 12, 1908, the above recommendations were approved, to take effect July 1, 1908. These recommendations were also approved by the American Society of Mechanical Engineers and the American Institute of Mining Engineers, and since July 1, 1908, the library staff has been in charge of Miss Howard. Previously to that date each library had its own librarian with an assistant working independently of the others. The new arrangement has proved to be entirely satisfactory and a decided improvement over the previous method of operation.

The following tabulations give the state of the five funds from which the Library Committee is entitled to draw·

DONATIONS (GENERAL LIBRARY FUND)

Dr.		Cr.	
Balance May 1, 1908	$244.15		
Interest May 1, 1909	7.36	Unexpended	$251.51
	$251.51		$251.51

CARNEGIE FUND

Balance May 1, 1908	3,168.19		
Interest	88.72	Wheeler Bibliography	3,256.91
	$3,256.91		$3,256.91

MAILLOUX ENDOWMENT FUND ($1,000)

(Proceeds for the maintenance of certain sets of periodical publications)

Balance May 1, 1908	$ 17.35	Subscriptions	$ 17.00
Interest May 1, 1909	30.00	Unexpended	30.35
	$ 47.35		$ 47.35

INTERNATIONAL ELECTRICAL CONGRESS OF ST. LOUIS, 1904 FUND

Principal, May 1, 1908	$2,146.12		
Additions to Fund	121.88		
Invested in New York City 4½% Bonds	$2,268.00		
Interest May 1, 1909		Unexpended	$124.72

WEAVER FUND

Balance May 1, 1908	$ 75.00	Expended	$ 9.56
		Unexpended	65.44
	$ 75.00		$ 75.00

INSTITUTE APPROPRIATION ACCOUNT

Dr.		Cr.	
Appropriation for maintenance for year ending October 1, 1909	$3,000.00	Librrian and assistants	$1,250.68
		Cataloging	199.17
		Desk attendant	68.01
		Insurance	88.79
		Binding	247.75
		Supplies	51.69
		Subscription	89.25
		Books	397.12
		Typewriter	15.70
		Printing	17.66
		Book plates	24.50
		Miscellaneous	10.27
		Unexpended	539.41
	$3,000.00		$3,000.00

The general statistics of the Library and its valuation are shown in the following tabulation:

STATISTICS OF LIBRARY, MAY 1, 1909

Source	Titles	Volumes	Pamphlets	Valuations
Report of May 1, 1908	7,976	11,828	565	$23,406.55
PURCHASES:				
Mailloux Fund	4	8		17.00
Weaver Fund	8	10		9.65
Institute Appropriation	120	174		397.12
Periodicals	170	218		436.00
Gifts and Exchanges		1,277		300.00
Totals	8,278	13,515	565	$24,566.23
Duplicates	501	714		900.00

In the following table are given the figures for the total valuation of the library property:

Books	$24,566.23
Stacks	1,761.05
Furniture, Catalogue Cases, etc	208.28
	$26,535.56

LIBRARY ATTENDANCE

	Day	Evening
May, 1908	400	196
June "	419	136
July "	441	Closed
August "	362	Closed
September "	393	125
October "	381	180
November "	425	200
December "	520	441
January 1909	485	250
February "	533	254
March "	535	280
April "	529	219
Totals	5,423	2,281
Total day and evening		7,704

IMPORTANT GIFTS AND ACCESSIONS

Mr. Edward D. Adams has continued his special interest in the library and has donated as heretofore the yearly *Proceedings* and *Transactions* of the Royal Society of London, and the additional volumes of the International Catalogue of Scientific Literature. He has also borne the expense of binding the volumes of the catalogue heretofore added to the library. The fund of $1000, known as the " C. O. Mailloux Fund," has again been drawn upon for the subscription price of the four important periodical sets originally presented by Mr. Mailloux to the library. The proceeds of the International Congress Fund, which is now invested so as to yield an annual income of nearly $100, has been drawn upon for the very recent purchase of several reports of international congresses and international electrical exhibitions. The Public Service Commission of the Second District, State of New York has presented a set of its publications. Some incomplete sets have been entirely or nearly completed, and a complete set of " Terrestrial Magnetism " has been added. The principal purchases have been publications of recent years.

GENERAL INVENTORY AND INSPECTION

This work which was in progress at the time of the last annual report has been continued and completed. The errors and deficiencies discovered have been corrected by the present librarian and the entire collection thus put into excellent shape for the preparation of the union card catalogue.

THE UNION CARD CATALOGUE

Early in the year it was decided to prepare a union card catalogue of all the books belonging to the three founder societies. For this purpose an expert cataloger was employed and the work has progressed so rapidly that the catalogue is already completed. A new card cabinet of 180 drawers with a capacity for nearly 200,000 cards has been installed in the general library and the union catalogue is now in public use.

TRADE CATALOGUES

A new feature of the library is the file of trade and manufacturers' catalogues. These are arranged in the drawers of a vertical file and are indexed both by names and subjects. As new editions of catalogues are received the old ones are displaced.

THE ENGINEERING INDEX

An effort has been made to have available for the use of searchers every general index to engineering literature, and the library now has a fine collection of such reference books. These include Kerl's *Repertorium*, The Royal Society's *Catalogue of Scientific Papers* and its successor, the *International Catalogue of Scientific Literature*, both of which were the gift of Mr. Edward D. Adams; a complete set of the *Engineering Index*, a complete set of *Science Abstracts*; and many other valuable helps. Reference to the *Engineering Index* is facilitated by clipping each monthly issue as it appears and arranging the titles on cards which are then arranged in a subject classification for the use of the public. This index is thus kept up to date as closely as possible. The publishers of the

Electrical World have just contributed a complete set of its semi-annual indexes, specially bound with thumb index tabs, making a very handy and serviceable volume.

TELEPHONE RECORDS

The very vaulable set of telephone records presented to the library by the American Bell Telephone Company, and comprising about 100 volumes, is now being catalogued in detail. Each volume contains many pamphlets and other material, either printed or in manuscript form, and it is hoped that the catalogue when completed may be printed by the Institute so that the contents of this vaulable set may be made available for more general consultation.

HARMONIOUS OPERATION

We take pleasure in reporting that the authorities in charge of the libraries of the American Institute of Mining Engineers and the American Society of Mechanical Engineers have coöperated with us to bring about an efficient service under conditions that are not always the most favorable. The three libraries here housed together still remain under separate and independent ownership, but each has shown its desire to make the various collections as useful as possible to the members of all societies alike as well as to the general public. A further movement in this direction is now under way, and a recommendation that each society print and circulate to all members alike the accessions of all three libraries is now being considered by each society.

HISTORICAL MUSEUM

While we have not actively pushed the affairs of the Historical Museum which was established about three years ago the matter has had our attention from time to time. At present there seems especially to be no satisfactory space at our disposal for the proper carrying out of the original plan. The space originally set aside on the twelfth floor has been required for library purposes during the past year and with the increase in the library this condition will no doubt continue. The project however is one that is important and deserves some more adequate provision for the preservation and display of historical apparatus.

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OF

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